ENVIRONMENTAL STUDIES IN THE WAWA AREA 1969 – 1977

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SUMMARY

An iron-sintering plant constructed at Wawa, Ontario has operated and expanded since 1939. The emissions, primarily as SO_2, from the sinter plant have produced an environmentally altered area to the northeast of the plant under the influence of the prevailing winds. A number of environmenal studies have been carried out in the Wawa area. This report summarizes data obtained in these studies (with emphasis on the more recent data) and indicates the nature of some of the ongoing studies.

Ambient air is monitored in the Town of Wawa and at Goudreau, 35 km NE (summer months only) for SO_2. The data obtained in Wawa indicated that the Province of Ontario criterion of 0.25 ppm for one hour was exceeded on 111 hours in 1976 and 77 hours in 1977. The 24-hour Provincial Criterion was exceeded on 12 days in 1976 and 6 days in 1977. At the Goudreau monitor, the Provincial 1-hour Criterion was exceeded on 61 occasions in 1976 and 17 occasions in 1977. The 24-hour Provincial Criterion was exceeded at Goudreau on 7 days in 1976 but only once in 1977. Sulphation plates exposed at a number of locations in the Wawa area were frequently found to be in excess of the Provincial Criterion. Sites nearest to the sinter plant (within 30 km) generally showed the highest sulphation values. The Provincial Criterion was exceeded on 14 occasions in 1976 and 16 occasions in 1977. Particulate emissions from the sinter plant as measured by high volume air samples did not appear to adversely influence the air quality in the Town of Wawa in 1976 and 1977.

A voluntary program of controlling SO_2 emissions from the sinter plant was initiated by Algoma Ore Division in 1976. The program was intended to ensure that excessive (greater than 0.5 ppm SO_2 hourly average) fumigations do not occur in the Town of Wawa. SO_2 data from the monitor in the Town of Wawa is telemetered to the sinter plant. The plant operators are then able to utilize the air quality data in a program of curtailing sinter plant operations and thereby reducing SO_2 emissions.

Typical SO_2 injury to vegetation was observed each year in the Wawa area. The most severe injury was usually observed at plots nearest to the sinter plant in the northeast direction. A heavy fumigation in 1975 severely damaged vegetation in the Town of Wawa. SO_2 injury to vegetation was also observed in 1976 and 1977 but the injury was less severe and less extensive.

The condition of vegetation at plots established in the Wawa area was documented each year. A decline in the conditions of trees and shrubs was noted at plots nearest to the sinter plant. This study was revised and enlarged in 1977. Ground flora population studies indicated that the numbers of species and numbers of plants were different among plot locations but no changes were determined between years indicating that any changes in the fume damage zone are not occuring very rapidly. The composition of vegetation types present at the plot sites have apparently been influenced by the stresses created by repeated SO_2 fumigations.

A program of soil and vegetation sampling at the established plot sites indicated elevated sulphur and arsenic concentrations in the samples. The highest concentrations were found nearest to

the sinter plant and to be influenced by the prevailing wind. A more intensive program of soil sampling in 1975 demonstrated an accumulation of arsenic in soil in close proximity to the sinter plant and to approximately 15 km NE. At present, the significance of these elevated arsenic values, especially in the presence of sulphur dioxide, from the toxicological or health point of view has not been determinted. Manganese, and to a lesser extent, iron and sulphur concentrations in the soil followed a pattern similar to that of arsenic.

A snow sampling program conducted in 1975 and 1976 indicated elevated sulphate, iron and arsenic in the melt water of snow samples collected in close proximity to the iron sintering plant.

Based on available data, sintering activity at Wawa has caused measurable alteration in the water chemistry of area lakes. Observed effects include elevations in aqueous sulphate and cation levels and sediment-borne metal concentrations. Although an influence of sinter plant emissions on lake waters was evident, present water quality does not merit concern from a public health viewpoint. In terms of effects on aquatic biota, existing water quality in the study lakes does not, in general, appear directly problematic. However, it is possible that single precipitation events may induce short term water quality problems associated with acidic precipitation and resultant adverse biological effects.

In general, pH depression does not appear to be a problem in the study lakes, and calculations of H^+ assimilation capacity indicate that the lakes are able to effectively neutralize significant acidic inputs derived from atmospheric emissions. It is important to note that, based on ancillary information, at least some area lakes i.e. Lagarde and Blueberry, are exceptions, and do exhibit depressed pH, apparently due to atmospheric inputs.

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I INTRODUCTION

In 1939, the Algoma Steel Corporation constructed an iron-sintering plant at Wawa, Ontario. Operations were expanded in 1949. In the sintering process, iron ore with high sulphur content (15%S) was heated and the waste gases were exhausted through two 46-metre stacks. Under the influence of the strongly prevailing south westerly winds, the waste gases (primarily as SO_2) were carried northeast of the sintering plant into the general area of the Magpie River valley. The high concentrations of sulphur dioxide severely damaged most of the higher forms of vegetation for approximately 13 km to the northeast. Beyond this severely damaged area, partial kill and light damage gradually merge with vegetation displaying less injury, until normal conditions prevail at approximately 50 km to the northeast.

In 1954 and 1958, two new stacks, each 76 metres in height were erected, and commencing in 1962, the plant utilized iron ore with low sulphur content (less than 4%S) during the growing season. These measures were taken in order to reduce atmospheric SO_2 concentrations with concomitant reductions in injury to vegetation and improved environmental quality in the vicinity of Wawa.

A report (1) issued in 1957 attempted to measure the loss in potential revenue to the crown from decreased land values, fish and wildlife losses and timber management losses in the affected area. The dollar value of the potential losses was over $500,000 in 1957 dollar values therefore the present losses in terms of current dollar values would be considerably greater.

A preliminary ecological study of the Wawa area was conducted in 1960 by Gordon and Gorham (9). While much of the basic information obtained by them has been confirmed, more recent and more detailed studies have shown that interpretation of their data must be considered in light of the study methods which they employed (14, 15).

Each summer between 1952 and 1974, the Ministry of Natural Resources (formerly the Department of Lands and Forests) carried out a program of aerial mapping of vegetation injury in the Wawa area. Some results of this program are presented in Section III.

In 1958, the Ontario Department of Mines installed a Leeds and Northrup SO_2 recorder at Magpie 14 km NE of the sinter plant. In 1961, when the lumber mill was moved from Magpie, the recorder was installed at Goudreau 35 km NE of the sinter plant. An additional recorder was installed in the Town of Wawa in 1969.

A series of six lead peroxide candles to measure rates of sulphation were exposed at several locations in the Wawa area starting in 1961. In 1970, the lead peroxide candle program was realigned to more closely correspond to locations where vegetation study plots were established by the Ministry of the Environment in 1969.

In 1963, water quality downwind of the Wawa sinter plant was shown as having been affected by emissions from the sinter plant (9). This was supported by data obtained in a bulk precipitation study (12). A water sampling program

was carried out in 1971-1972 as a cooperative program between Ministry of the Environment and Ministry of Natural Resources to monitor the water quality of a number of lakes in the Wawa area. A revised water sampling program was conducted in 1975.

This report summarizes data obtained in the air quality monitoring programs, the water quality monitoring programs and the results of the vegetation plot program. The ongoing studies are also outlined.

II AMBIENT AIR QUALITY MONITORING

In 1976 and 1977, the Ministry of the Environment continued its ambient air quality monitoring program in the Wawa area. As in previous years, the program consisted of the continuous monitoring of ground level concentrations of SO_2 in the Town of Wawa and in Goudreau (35 km northeast of Wawa); determination of sulphation rates during the growing season at various sites in the Wawa area; and the determination of the levels of suspended particulates in Wawa.

A) Sulphur Dioxide Measurements

i) Sulphur Dioxide Emissions (1961-1977)

A summary of the SO_2 emissions from the Algoma Ore Division plant is presented in Figure 1 for the May to September period from 1961 to 1977. These emission rates were determined from mass balance values reported by the Algoma Steel Company, Algoma Ore Division, Wawa. During this 17 year period, SO_2 emission rates from the sinter plant during the growing seasons have ranged from about 55,000 tons to 80,000 tons. In 1969 and 1970 the emissions were lower ($\sim$40,000 tons) due to extended plant shut-downs as a result of labour strikes. As of 1962 the sinter plant has been utilizing iron ore with lower sulphur content (< 4%S) during the growing season in order to reduce SO_2 emissions to the natural environment when vegetation is more susceptible to injury.

ii) Sulphur Dioxide Ground Level Concentrations (1976-1977)

In 1976 and 1977, the Ministry of the Environment continued to monitor the levels of SO_2 at Hillcrest Avenue in the Town of Wawa (see Figure 3) and also at Goudreau, located approximately 35 km NE of the sinter plant (Figure 2). As in the past, the monitor at Goudreau was operated and maintained during the growing season only (May to October), whereas the Hillcrest Avenue monitor was operated throughout the year. At this latter site, the monitor has been operated throughout the year since 1976. Prior to this (i.e. from 1969 to 1975), the SO_2 analyzer ran from May to October of each year. SO_2 data collected during that period have been presented in several reports prepared by Dreisinger and McGovern and also by McGovern and Balsillie (14, 15, 16).

A summary of SO_2 data collected at the two stations in 1976 and 1977 is presented in Tables 1 to 4. The tables present the total number of valid hourly readings collected, the monthly average concentration, the maximum 1-hour and 24-hour average values and the frequency of exceedance of the 1-hour and 24-hour Provincial Criteria for each month that the monitors were operating. At the Hillcrest Avenue station, a total of 7569 hours and 8281 hours of valid data were collected in 1976 and 1977 respectively. Instrumentation problems encountered in April of 1976 were largely responsible for the lower number of valid readings in 1976. The annual mean concentration was 0.014 ppm in 1976 and 0.010 ppm in 1977. The Provincial annual criterion for acceptable SO_2 levels is 0.02 ppm, such that on an annual basis, the mean SO_2 levels at the Hillcrest Avenue station in Wawa during 1976 and 1977 were within acceptable limits.

However the 1-hour and 24-hour Provincial Criteria of 0.25 ppm and 0.10 ppm respectively were exceeded on numerous occasions in both years as shown in Tables 1 and 2. In 1976, hourly readings in excess of 2.0 ppm were recorded on a few occasions. In addition there were 47 hours in excess of 0.50 ppm, of which 17 hours were in excess of 1.00 ppm (see Table 5). In 1977, 36 hours greater than 0.50 ppm were recorded, of which 10 hours exceeded 1.0 ppm (see Table 6). During 1976, the 1-hour criterion was exceeded on 111 occasions, and the 24-hour criterion was exceeded on 12 days. In 1977, the 1-hour criterion was exceeded on 77 occasions, whereas the 24-hour criterion was exceeded on 6 days. Hence the frequency of excessive fumigations and the average SO_2 levels were slightly lower in 1977 than in 1976.

Inspection of Tables 1, 2, 5 and 6 reveals a strong seasonal dependence of the SO_2 levels and of the frequency distribution of excessive values at the Hillcrest Avenue station. This is further summarized in Table 7. In this context the seasons were defined as follows: winter (January-March), spring (April-June), summer (July-September) and fall (October-December). Of the 188 hourly readings in excess of the Provincial Criterion in 1976 and 1977, 165 hours (or 88%) were obtained during the fall and winter months. In addition, 16 of the 18 daily means with 24-hour average concentrations in excess of 0.10 ppm were also monitored during the fall and winter months. The greater frequency of excessive ground level concentrations and the resulting higher SO_2 levels during the fall and winter months is largely attributed to prevailing north and northwest winds which direct SO_2 emissions from the sinter plant over the Town of Wawa. In addition, SO_2 emission rates from the sinter plant are higher during the non-growing seasons, largely due to the processing

of higher sulphur (> 4%S) ore. Finally, a voluntary supplementary control system (SCS) instituted by the Algoma Ore Division in 1976 (to be discussed in more detail in Section iii) has contributed significantly in decreasing the frequency and intensity of SO_2 ground level fumigations during the growing seasons in 1976 and 1977.

The SO_2 data collected at the Goudreau station in 1976 and 1977 are summarized in Table 3 and 4. In 1976, 2410 hours of valid data were collected with an overall seasonal average of 0.030 ppm. The 1-hour Provincial Criterion was exceeded on 61 occasions and the 24-hour criterion was exceeded on 7 days. The majority of the excessive values were recorded in August. The average for the month was 0.049 ppm. In 1977, 3176 hours of data were collected, resulting in a seasonal average 0.016 ppm. The 1-hour Provincial Criterion was exceeded on 17 occasions and the 24-hour criterion was exceeded on 1 day. The monthly group frequency distribution of the SO_2 hourly values for both years is presented in Tables 8 and 9. As in previous years, over 90% of the readings were in the 0 to 0.10 ppm range. The 1976 growing season was by far the worst for excessive SO_2 levels at Goudreau since 1965 as shown below:

YEAR	NO. OF HOURLY READINGS	AVERAGE(ppm)	NO. OF TIMES ABOVE PROVINCIAL CRITERION 1-hr	24-hr
1965	3714	.010	11	1
1966	3302	.011	14	0
1967	3495	.018	17	1
1968	3589	.014	21	0
1969	3505	.005	1	0
1970	3185	.003	0	0
1971	2535	.009	6	0
1972	2441	.008	2	0
1973	3356	.014	35	3
1974	2517	.016	18	2
1975	2696	.013	11	0
1976	2410	.030	61	7
1977	3176	.016	17	1

iii) Voluntary Supplementary Control System

In the summer of 1976, the Algoma Ore Division in Wawa instituted a voluntary supplementary control system at the sinter plant aimed at eliminating excessive (> 0.50 ppm SO_2 hourly average) ground level fumigations in the Town of Wawa during the growing season. This system consists of curtailing sinter plant operations, and hence SO_2 emissions, when measured SO_2 levels at the Hillcrest Avenue station (operated by Ministry of the Environment staff) are excessive. The Algoma Steel Corporation purchased and installed a data averaging and telemetering system for the Hillcrest Avenue station in order to telemeter the "real time" signal and the hourly average SO_2 values to the sinter plant control room, thus providing plant operators with both the instantaneous and hourly SO_2 readings from the monitoring station on a continuous basis. The control program also includes meteorological forecasting of adverse dispersion conditions and model predictions of ground level SO_2 concentrations in the Wawa area.

The following table summarizes the frequency of occurrence of SO_2 hourly readings greater than 0.50 ppm and the maximum readings recorded during the period April to September from 1973 to 1977:

YEAR	NO. OF READINGS > 0.5 ppm	MAX. READING (ppm)
1973	10	1.79
1974	22	1.31
1975	16	2.13
1976	8	1.13
1977	2	1.06

During the 1976 growing season, the Hillcrest monitor recorded 8 hours > 0.5 ppm whereas during the 1977 season only 2 hours exceeded that value. The sinter plant, during these periods curtailed sinter production on a number of occasions in order to reduce SO_2 emission rates. For example, for the period April to September 1977, the Algoma Ore Division reported that curtailments in sintering activities for SO_2 control resulted in the loss of about 13,600 gross tons of potential sinter material. During the 1973, 1974 and 1975 seasons, when emission controls were not implemented, the number of readings in excess of 0.5 ppm were considerably greater than in 1976 and 1977. In addition the values of the maximum reading were somewhat lower in both 1976 and 1977 as indicated in the table.

Consequently, it would appear that the initial attempt by the Algoma Steel Corporation, Algoma Ore Division, at implementing a supplementary control system during the growing season has been effective in reducing the number of hourly average SO_2 concentrations greater than 0.5 ppm in the Town of Wawa.

iv) Sulphation Rates (1976-1977)

During the 1976 growing season a total of 10 lead peroxide candles were exposed in the Wawa area in order to determine sulphation rates. These sulphation monitors were located adjacent to vegetation plots as shown in Figure 2. The candles were exchanged approximately every 30 days and subsequently analyzed for sulphur trioxide. The sulphation rate is expressed as the number of milligrams of sulphur trioxide per 100 cm^2 of exposed candle area per day, based on a 30 day exposure average.

The results of the candle survey in 1976 are shown in Table 10. As in the past, the highest sulphation values were obtained at locations within about 30 km of the sinter plant in Wawa. Sulphation rates in excess of 1.0 mg $SO_3/100cm^2/day$ were repeatedly obtained at the Lucy Pit and Parks Lake plots located about 10 km and 16 km NE of the sinter plant respectively. The candles at the Dubreuil Rd. and Obatanga Park sites are sufficiently removed from the sinter plant that the sulphation rate levels measured there can be considered as background levels. The sulphation rates at these locations are about one order of magnitude lower than at the other locations.

During the 1976 growing season the Provincial criterion of 0.7 mg $SO_3/100cm^2/day$ was exceeded a total of 14 times at locations within the fume damage area. The majority (9 samples) of these excessive levels were recorded at the Lucy Pit and Parks Lake sites. In 1975, the Provincial criterion was exceeded 9 times, with the majority of excessive levels again recorded at the Lucy Pit and Parks Lake sites.

During the 1977 growing season, the sulphation candles were replaced with sulphation plates. These passive monitoring devices also determine sulphation rates. The only difference between the candle and the plate is physical i.e. the lead dioxide impregnated substrate is housed in a 55 mm diameter plastic petri dish. During exposure, the petri dish is exposed in an inverted position with the dish cover removed. The sulphation plates are also exposed for approximately 30 days. The sulphation monitoring sites were identical to those in 1976.

The results of the 1977 sulphation survey are presented in Table 11. Values in excess of 4.0 mg SO_3/100 cm^2/day were obtained at the Lucy Pit and Parks Lake sites. These are the highest values ever measured at both locations and also in the Wawa area by a government monitoring agency. Sulphation rates at the other sites generally decreased with increasing distance from the sinter plant as in past years. However, the mean levels in 1977 were higher at all sites in comparison with the levels measured in 1976. During 1977 the Provincial criterion was exceeded at total of 16 times. Half of these excessive levels were obtained at the Lucy Pit and Parks Lake sites.

The mean sulphation rate for the ten monitoring sites in 1976 and 1977 was 0.58 and 0.94 mg SO_3/100 cm^2/day respectively. This amounts to a 62% increase in the sulphation values. Huey (11) and Ministry staff of the Air Quality Lab (8) have indicated that the plates, on average, yield higher values than the candles. The difference between the plates and the candles may be as high as 20% (11) and 30% (8). The comparison of plates to candles is presently under investigation by the Air Quality Laboratory in order to arrive at a better estimate of the discrepancy. However, it appears that the increase in sulphation levels from 1976 to 1977 is too large to be accounted for solely on the basis of differences between the plates and the candles. Hence the higher sulphation values measured in 1977 are believed to have resulted largely from increased ambient SO_2 levels.

B) High Volume Sampling Survey

In 1976, a high volume air sampler was operated at two locations in the Town of Wawa:

a) at the intersection of Churchill Avenue and Mission Road

b) at the Hillcrest Avenue SO_2 monitoring station.

The approximate locations of these sites are shown in Figure 3. The high volume air sampler determines the mass concentration of suspended particulate matter in the air, i.e. the fraction of dust particles too small to settle to the ground under the influence of gravity. This instrument draws approximately 1.5 cubic metres of air per minute through a preweighed glass fiber filter.

The resultant increase in the weight of the filter as the sampler is operated then determines the amount of dust collected by the filter. The results are expressed in micrograms per cubic metre (ug/m^3) of air sampled. The sampler is operated continuously for a 24 hour period, usually every sixth day coincident with the Provincial high volume sampling survey. In addition to total loading, the filters can be analyzed for various elements and compounds at the Air Quality Laboratory.

i) Churchill Avenue - Mission Road Site

During 1976, a total of 44 samples were collected. The data are presented in Table 12. The Provincial Criterion of 120 ug/m^3 for a 24-hour sampling period was exceeded on 2 occasions with values of 185 ug/m^3 (March 16) and 193 ug/m^3

(July 5). For the 44 samples collected the geometric mean was 35 ug/m^3, which is well below the annual Provincial Criterion of 60 ug/m^3. Table 12 indicates that the dust levels were generally higher from April to September when entrainment from ground level is greatest. On the basis of evidence presented in the 1975 report "Air Quality Assessment Studies In the Wawa Area", high volume air sampling at that site was discontinued in the fall of 1976 owing to the large contribution to the particulate levels from dust in a nearby parking lot.

The filters exposed at that site in 1976 were also analyzed for Zn, Fe, Pb and Mn*. The results of these analyses are presented in the following table:

Element	No. of Samples Analyzed	Maximum Value (ug/m^3)	Mean Value (ug/m^3)	Provincial 24-hr Criterion (ug/m^3)
Fe (Iron)	43	12.8	3.2	no criterion
Pb (Lead)	44	0.9	0.3	5
Mn (Manganese)	13	0.7	0.2	50
Zn (Zinc)	43	2.9	0.1	no criterion

The concentration of these elements in the suspended particulate fraction were quite low and well within existing Provincial Criteria.

* The high volume air sampling technique presently used is not suitable for monitoring airborne arsenic.

ii) Hillcrest Avenue Site

A high volume air sampler was installed at the Hillcrest Avenue station in Wawa in April 1976. A total of 37 samples were collected that year. The total suspended particulate data are presented in Table 13. All values were within the Provincial Criterion of 120 ug/m^3 for a 24-hour sample. The geometric

mean of 30 ug/m^3 was well within the Provincial Annual Criterion of 60 ug/m^3. The uncertainty in the geometric mean of 30 ug/m^3 at the 95% confidence level is $\pm$ 7.5 ug/m^3. The total suspended particulate data for 1977 is presented in Table 14. A total of 26 samples were collected in 1977. The values ranged from 13 to 65 ug/m^3 with a geometric mean of 27 ug/m^3. The uncertainty in the geometric mean at the 95% confidence level is $\pm$ 5.1 ug/m^3 such that the dust levels were within the Provincial annual criterion of 60 ug/m^3.

In 1976 and 1977 the filters were analyzed for Fe, Pb, Mn and Zn. The results are presented in Table 15. The values were consistently low and also well within existing criteria.

Consequently, particulate emissions from the Wawa sinter plant appear to have very little impact on the air quality in the Town of Wawa. This is substantiated by the low levels of total suspended particulate measured at two locations and also by the low concentrations of iron in the particulates. In addition, on days when emissions from the sinter plant were impinging on the station (determined from inspection of the SO_2 data at the Hillcrest station), the total suspended particulate levels were generally less than 60 ug/m^3 for a 24-hour period, whereas the iron levels were less than about 6.0 ug/m^3.

III VEGETATION INJURY

A) Potentially Injurious Fumigations

Based on observations made in the Sudbury area, Dreisinger attempted to relate SO_2 injury to vegetation to the duration and concentration of SO_2 measured during a fumigation (5,6). It was found that injury could occur under the following conditions:

0.95 ppm SO_2 for 1 hour
0.55 ppm SO_2 for 2 hours
0.35 ppm SO_2 for 4 hours
0.25 ppm SO_2 for 8 hours

If any of these conditions were met in the daylight hours, then the fumigation intensity was assigned a value of 100 for convenience. If the fumigation intensity value was 100 or over, then the fumigation was termed a potentially injurious fumigation (P.I.F.). A P.I.F. does not always result in injury since other factors such as species sensitivity, growing season and environmental factors also have some bearing on susceptibility to injury. Using this system, the numbers of P.I.F. at each recorder station could be calculated.

The numbers of P.I.F. recorded at the two SO_2 monitors in the Wawa area since 1971 are indicated below:

Year	Wawa	Goudreau
1971	4	0
1972	3	0
1973	4	3
1974	3	1
1975	4	1
1976	3	0
1977	2	0
TOTAL	23	5

Greater numbers of P.I.F. were recorded at Wawa than at Goudreau however, the majority of the fumigations at Wawa occurred during the months of September and October as indicated in the following table. This demonstrates the influence of the shift in prevailing wind direction which occurs at this time of year. The shift is from southwest in summer months to northwest in the fall. At Goudreau, the fumigations were spread throughout the growing season.

MONTH	WAWA	GOUDREAU
May	1	1
June	2	0
July	2	2
August	1	0
September	8	1
October	9	1
TOTAL	23	5

The dates and intensity values of P.I.F. recorded at the Wawa area monitors in 1976 and 1977 are presented in Table 16.

B) Vegetation Injury at Surveillance Plot Locations

At the time of each monthly visit to the vegetation plots in the Wawa area, evaluations of the severity of SO_2 injury symptoms on foliage of various plant species were made. An account of injury observed prior to 1976 has been included in earlier reports (14, 15). Injury observed at each surveillance plot in 1976 and 1977 is summarized in Tables 17 and 18. The tables are based primarily on the observed degree of injury to white birch foliage.

The most commonly injured species included white birch, trembling aspen, bracken fern and raspberry, all of which are known to be sensitive to SO_2. SO_2 injury is also commonly observed on foliage of aster, fireweed, mountain maple, showy mountain ash, pin cherry, maianthemum and bindweed.

In both years, the most severe injury was observed at Lucy Pit, Parks Lake and Finger Lake. These three locations are nearest to the sinter plant in the northeast direction. Light injury was observed at Perry Lake and Garbe Lake in 1977 but only trace amounts of injury occurred in 1976. No SO_2 injury was observed at Goudreau in 1976 but a few trees were lightly injured in 1977. At the Highway 17 location, moderate injury was recorded in 1976 but only a few trees were lightly injured in 1977. No injury was observed at the Troupe Lake, Dubreuilville Road or Obatanga locations in either year.

Moderate to severe SO_2 injury to foliage of white birch and trembling aspen was observed in September 1977 in an area approximately 3 km E of Michipicoten Harbor. Senescence related to the lateness of the season made it difficult to assess the extent of the injury.

C) Vegetation Injury in the Town of Wawa

SO_2 injury to vegetation has been observed on a number of occasions in the Town of Wawa. A severe fumigation in late July 1975 caused extensive damage to a number of plant species (14). The approximate area over which visible injury to vegetation occurred is shown in Figure 4.

Injury to various vegetation species also occurred in both 1976 and 1977 in the Town of Wawa, however, the severity of injury was considerably less than that of 1975. The areas in which the injury was observed in August 1976 and August 1977 are shown in Figures 5 and 6 respectively. Severe injury to turnip foliage in close proximity to the SO_2 recorder was also observed on October 13, 1976. A fumigation occurred on October 6, 1976 and included a maximum hourly average SO_2 reading of 2.12 ppm SO_2. This fumigation was not included in calculations for P.I.F. since it occurred during a dark period. Turnip is usually considered to be sensitive to SO_2. Due to the lateness in the season, no other plant species in the garden was injured.

D) Vegetation Injury Caused by Other Agents

The drought conditions which were experienced during 1975, continued in 1976, however, in 1977 frequent rainfalls alleviated this problem. Spruce budworm continued to be a problem with spruce and fir in the Wawa area in both 1976 and 1977. Basswood looper (Erannis tiliaria) caused extensive defoliation, particularly of showy mountain ash in 1977. A variety of mite and fungal disease injury were observed on various plant species in each year. The condition known as "white birch die back" of mature trees remained as a problem in the Wawa area in each year. The cause of this condition is unknown, however, there was no obvious relationship between the condition and the proximity of the sinter plant. Many of the white pine trees growing to the south and east of the fume damage area exhibited symptoms of chlorosis of the foliage in 1976. The cause of the chlorosis could not be readily ascertained, therefore, a study of the condition of the white pine was initiated in 1977. (See Section IX).

IV VEGETATION PLOT STUDIES

A) Tree Crown Classification

In 1969, six permanent vegetation study plots were established in the area northeast of Wawa where acute SO_2 injury to vegetation had been observed in previous years. Two control plots were established outside the fume damage area. A ninth plot was established in 1974 at Lucy Pit. Also in 1974, the plot at Herman Lake was relocated to Troupe Lake and the Crouche Lake plot was moved to Dubreil Road. In 1975, an additional plot was set up 1.6 km southwest of the sinter plant. The locations of the 10 plots are listed below and are shown in Figure 2. A description of the plot locations and plot sites is included in the Appendix.

PLOT	YEAR ESTABLISHED	LOCATION*
Highway 17	1975	1.6 km SW
Lucy Pit	1974	10 km ENE
Parks Lake	1969	16 km NE
Finger Lake	1969	19 km NE
Perry Lake	1969	26 km NE
Garbe Lake	1969	30 km NE
Goudreau	1969	35 km NE
Troupe Lake	1974	40 km NE
Dubreuil Road	1974	45 km NNE
Obatanga Park	1969	56 km NW

* Distance and direction from sinter plant.

At the time of the plot establishment 10 trees (white birch and/or trembling aspen) were selected and tagged over an area of 20 metres by 20 metres. Ten shrubs (mountain maple, mountain ash, prairie willow, dogwood, pin cherry, speckled alder, beaked hazel or serviceberry) were also tagged over the same area at each location. The heights and diameters of all tagged individuals as well as the general condition of the individuals were recorded. The incidence of SO_2 injury, insect injury and

the general condition of the tagged individuals has been recorded each month of the growing season (May to October) since the plots were established.

During June, July and August of each year, the tagged trees and shrubs on the Wawa area vegetation study plots have been rated according to a crown classification system developed by the Canadian Forestry Service. Under this system a healthy tree or shrub would be rated 1A; an individual in the state of some decline, 1B, 2A, or 2B; a specimen in the state of moderate decline, 3A, 3B, 4A or 4B; one in a state of severe decline, 5A or 5B; and a dead specimen, 6A. In assessing the crown conditions, such factors as SO_2 injury, insect and disease injury, mechanical injury and drought have been considered.

The distribution of tree crown classifications of the tagged trees is presented in Table 19. All trees in plots established in 1974 or later remained in good condition. Since all trees tagged were originally in 1A condition, some decline of tree crown occurred in every plot established in 1969. Sixty percent of the trees at Parks, Finger and Perry Lakes declined although this value is considered high at Perry Lake where three trees were destroyed as the result of beaver activity. If this latter fact is borne in mind, there appears to be a good relationship between the amount of the tree crown decline in plots established in 1969 and distance from the sinter plant. The greatest decline occurred at Parks and Finger Lakes, the plots nearest to Wawa while plots at greater distances showed progressively less decline.

Decline in shrub crown condition occurred at every plot except Troupe Lake (Table 20). Although the greatest decline in crown conditions of the shrubs was demonstrated at Parks, Finger and Perry Lakes, it was not possible to directly implicate the emissions from the sinter plant for the decline since symptoms of moose browse were frequently seen on the tagged shrubs.

Following an examination of the available data up to 1976, this facet of the plot studies was terminated. In 1977, the study plan was revised and the plots were enlarged (see Section IX.... New Studies).

B) Ground Flora Population Studies

In 1969, two permanent grids (1m x 1m) were set up at each of the original 8 plot sites. Each August in 1969 to 1973, the grids were examined and the number of individuals of every plant species which occurred within the grid were counted. In 1975, the program was revised and 20 randomly selected grids were examined at each plot. The original grids have been retained and could be reactivated if required.

i) Studies 1969 - 1973

The existence of plant species in the permanent grids or in the vicinity of the grids at each plot was determined in 1971. An updated summary of this information based on additional observations is presented in Table 21. The species are divided into groups (trees, shrubs, herbs, grasses and sedges, ferns, clubmosses and horsetails). Species found within the grids are indicated by *, species found outside the grids are denoted by O.

The number of species found within the grids accounts for approximately half of the species present near the plot site (Table 21). The greatest numbers of species were found at Goudreau and Herman Lake. A number of species were found only at one or both of these locations and of these, many are introduced weedy species. This is not surprising since these two locations are close to centres of human settlement and weedy species tend to thrive in areas of human activity.

Data obtained from the ground flora population grids from 1969 to 1973 was subjected to a two-way analysis of variance. A

square root transformation to $(x + 1/2)$ was applied to overcome non-conformity of the data.

A summary of the analysis of variance of numbers of species found in the grids is indicated in the table below:

	Number of species of trees	Number of species of shrubs	Number of species of herbaceous plants	Total Number of species
Plots	F = 10.02**	F = 9.25**	F = 6.05**	F = 15.00**
Years	F = 0.71	F = 0.35	F = 0.71	F = 0.42
Plots X Years	F = 0.17	F = 0.15	F = 0.31	F = 0.14

** Significant differences exist at (P = 0.01) levels of confidence.

Statistically significant differences in numbers of plant species between plots could be determined for each different grouping of plant types. There was no difference in numbers of plant species from year to year indicating that the numbers of species in the study area had remained more or less constant over the study period.

The results of Student-Newman-Keuls (S.N.K.) mean separation tests for significant differences among the means of numbers of species per plot are indicated in the following table:

TESTS FOR NUMBERS OF SPECIES PRESENT

TREES	SHRUBS	HERBACEOUS PLANTS	TOTAL
Herman L.	Obatanga	Obatanga	Obatanga
Crouche L.	Finger L.	Herman L.	Herman L.
Finger L.	Perry L.	Parks L.	Finger L.
Garbe L.	Garbe L.	Garbe L.	Garbe L.
Perry L.	Parks L.	Finger L.	Perry L.
Obatanga	Goudreau	Perry L.	Parks L.
Parks L.	Herman L.	Crouche L.	Crouche L.
Goudreau	Crouche L.	Goudreau	Goudreau

Plots preceded by the same vertical line are not significantly different from each other.

The information in the above table indicates that there was no pattern in number of plant species at the difference plots with relations to the location of the sinter plant.

A summary of the analysis of variance of the numbers of individuals found in the grids is shown in the table below:

	Number of Trees	Number of Shrubs	Number of Herbaceous Plants	Total Number of Individuals
Plots	F = 3.37**	F = 3.33**	F = 12.66**	F = 14.73**
Years	F = 0.81	F = 0.32	F = 1.89	F = 1.99
Plots X Years	F = 0.31	F = 0.12	F = 0.38	F = 0.40

** Significant differences exist at (P = 0.01) level of confidence.

Statistically significant differences in numbers of individual plants were determined for each type of plant. The numbers of individuals did not change in the ground flora grids over the study period.

The following table shows the results of S.N.K. mean separation tests for significant differences among plot means:

TESTS FOR NUMBERS OF PLANTS PRESENT

TREES	SHRUBS	HERBACEOUS PLANTS	TOTAL
Perry L.	Perry L.	Perry L.	Perry L.
Herman L.	Herman L.	Parks L.	Parks L.
Crouche L.	Finger L.	Obatanga	Obatanga
Finger L.	Obatanga	Herman L.	Herman L.
Garbe L.	Goudreau	Finger L.	Finger L.
Obatanga	Garbe L.	Crouche L.	Crouche L.
Parks L.	Parks L.	Garbe L.	Garbe L.
Groudreau	Crouche L.	Goudreau	Goudreau

Plots preceded by the same vertical line are not significantly different from each other.

No pattern in the numbers of individual plants at the different plots in relation to the location of the sinter plant was apparent.

Species diversity index values based on the Shanon-Weaver transformation (13) were computed for combined pairs of grids at each of the plot locations in each year. These values are shown in Table 22. Similar values were determined for each location and there were no trends in relation to distance of the plots from the sinter plant. There was a weak trend to increased values with time at Perry Lake while a decreasing trend was observed at Obatanga Park. This information indicates that either no changes have taken place during the period of study or losses in one species have been offset by increases in another species.

ii) Study - 1975

In late July 1975, the occurrence (percent frequency) and cover of trees, shrubs and herbaceous plants were evaluated in 20 randomly distributed 1 x 1 m grids in and around the Wawa vegetation study plots. The data for percent frequency and cover for all vascular plant species found in the grids at each plot are summarized in Table 23.

These data show that while the total number of species did not change significantly with distance from the smelters, the relative percentage of tree cover, the number of tree species tended to increase with increasing distance from the sinter plant. Although the plot at Dubreuil Road is considered to be a control plot for other studies, the vegetation at this location is not typical for the area. In retrospect, the choice of this location was poor for ground flora studies. Data obtained at this plot will not be considered further in relation to the ground flora studies.

At Lucy Pit and Parks Lake, total tree coverage amounted to only 12% of the available space. In the absence of dense tree canopies at Lucy Pit, Parks Lake and Finger Lake, herbaceous plants responded to the increased light at Lucy Pit and Parks Lake while the most dense growth of shrubs occurred at Finger Lake. With the exception of Lucy Pit, where total coverage by vegetation was low due to the proximity of the total kill area and fire at an earlier time (1963), and Finger Lake where shrubs were a dominant component, there is a good inverse relationship between the percent coverage by trees and percent coverage by shrubs. In addition, coniferous tree species assumed an increasingly dominant position in the canopy with greater distances from the sinter plant.

V CHEMICAL ANALYSIS OF VEGETATION

A) Background

In 1969, the Ministry of the Environment established a program of vegetation sampling in the Wawa area. The sampling locations were adjacent to the permanent vegetation study plots. Sampling locations were moved or added at the same time as were the vegetation plots in 1973 to 1975. The following table lists the location of the plot, the year of establishment and the distance and direction of the plot from the sinter plant:

PLOT	YEAR ESTABLISHED	LOCATION*
Highway 17	1975	1.6 km SW
Lucy Pit	1974	10 km ENE
Parks Lake	1969	16 km NE
Finger Lake	1969	19 km NE
Perry Lake	1969	26 km NE
Garbe Lake	1969	30 km NE
Goudreau	1969	35 km NE
Herman Lake**	1969	38 km NE
Troupe Lake	1974	40 km NE
Crouche Lake **	1969	61 km NE
Dubreuil Road	1974	45 km NNE
Obatanga Park	1969	56 km NW

* Distance and direction from sinter plant
** Plot terminated in 1973

During July 1969, foliar samples of white birch, trembling aspen, mountain maple, showy mountain ash and grass foliage were collected at each plot and analysed for sulphur content. Four monthly foliar samples of the same species were made in 1970 and three monthly samples were collected in 1971, 1972 and 1973. In 1974, three monthly samples of white birch, mountain maple and grass foliage were collected. In 1975 and 1976, the sampling was reduced to white birch foliage collected in triplicate in July and August. The following table shows the chemical analysis performed each year on the vegetation samples.

	ELEMENT								
YEAR	S	As	Fe	Zn	F	Cd	Cr	Pb	Mn
1969	x								
1970	x	x	x	x	x				
1971	x	x	x	x					
1972	x	x	x	x					
1973	x	x	x	x		x	x	x	
1974	x	x	x	x				x	
1975	x	x	x						x
1976	x	x	x						

B) Excessive values

The Ministry of the Environment has conducted numerous vegetation and soil sampling programs throughout the Province of Ontario. Based on experience with these programs as well as on data published in the literature, a set of guidelines has been developed to indicate the concentrations of individual chemical elements which are considered to be excessive in plant tissue and soil. "Excessive" does not necessarily mean toxic, but is evidence of contamination above normal levels. This approach to contamination of vegetation and soil is useful to phytotoxicology investigators when interpreting the results of chemical analysis. These guidelines are useful for many types of vegetation but may not be applied to all vegetation, particularly for those species which accumulate specific elements. The following values are used in this report.

	CONCENTRATIONS CONSIDERED EXCESSIVE (ug/g)	
Element	Vegetation	Soil
Arsenic	8	25
Cadmium	5	8
Chromium	20	75
Copper	30	100
Fluoride	35	---
Iron	800	---
Lead	50	200
Manganese	500	1500
Zinc	250*	400

* Trembling aspen and white birch = 400

C) Analytical Results

i) Sulphur

The concentrations of sulphur measured in vegetation samples collected in the Wawa area are presented in Tables 24 to 28. Concentrations greater than 0.8% S in foliage are considered excessive.

The highest sulphur concentrations in the vegetation samples were usually recorded at Parks Lake and Finger Lake which are the nearest plots to the sinter plant in the direction of the prevailing wind. The sulphur concentrations decreased with distance from the sinter plant. At Highway 17 and Lucy Pit, sulphur concentrations were also elevated, however, since Highway 17 is upwind during the growing season and Lucy Pit is not directly in line with the prevailing wind, it should not necessarily be expected that these locations would have higher amounts of sulphur in the vegetation than at some more distant plots. The sulphur content of vegetation in 1969 and 1970 is lower than in later years and this can be attributed to lower emissions of SO_2 in those years (Figure 1).

ii) Arsenic

The arsenic concentrations in vegetation samples collected in the Wawa surveillance area are shown in Tables 29 to 33. Arsenic values greater than 8 ug As/g foliage are considered excessive.

Excessive arsenic concentrations were found in trembling aspen each year, except 1976, at Parks Lake. Excessive concentrations

of arsenic were found at least once in white birch at Lucy Pit, Parks Lake, Garbe Lake, Finger Lake and Highway 17. Mountain maple foliage samples collected in 1970 at Parks Lake contained excessive concentrations of arsenic. At Parks Lake, showy mountain ash contained excessive amounts of arsenic in 1970 and 1973. Samples collected in 1970 at Finger Lake and Garbe Lake also contained excessive concentrations of arsenic. One sample of grass foliage contained excessive amounts of arsenic in 1970.

iii) Iron

The concentrations of iron in vegetation samples collected at Wawa area surveillance plots are presented in Tables 34 to 38. Iron concentrations greater than 800 ug Fe/g foliage are considered to be excessive.

No samples of trembling aspen, showy mountain ash and grass foliage contained excessive amounts of iron, although samples from Parks Lake usually contained the greatest concentration of iron. Excessive concentrations of iron were measured in samples of white birch foliage collected at Highway 17, Lucy Pit and Parks Lake. Samples of mountain maple collected at Parks Lake in 1974 contained excessive concentrations of iron.

iv) Zinc

Zinc concentrations in vegetation samples are shown in Tables 39 to 43. Concentrations of zinc over 250 mg Zn/g foliage are considered to be excessive, however, since both trembling aspen and white birch are known to accummulate this element, only concentrations greater than 400 ug Zn/g foliage are considered

to be excessive. No samples contained excessive amounts of zinc, however, the trembling aspen and white birch contained higher concentrations than did the other plant species.

v) Manganese

Manganese concentrations measured in white birch foliage samples are shown in Table 44. A value of 500 ug Mn/g foliage has been established as an excessive concentration of manganese in plant tissue although there is an apparent variability among plant species in regard to manganese tolerance. Excessive concentrations of manganese were measured in the white birch foliage at all locations but there was no pattern of accummulation with respect to distance from the sinter plant and there was no correlation between the manganese in the foliage and in the soil.

vi) Fluoride

The concentrations of fluoride found in vegetation samples collected in 1970 in the Wawa area and are presented in Table 45. Concentrations greater than 35 ug F/g foliage are considered excessive. No sample contained excessive concentrations of fluoride.

vii) Lead

Lead concentrations in vegetation samples are shown in Table 46. No sample contained excessive concentrations of lead (50 ug Pb/g foliage). Samples from plots in the test area did not contain significantly higher amounts of lead than samples from the control locations.

viii) Cadmium

The concentrations of cadmium measured in vegetation samples collected in 1973 are presented in Table 47. The measured values are all below the concentration considered to be excessive (5 ug Cd/g foliage).

ix) Chromium

Chromium concentrations determined in vegetation samples collected in the Wawa area are shown in Table 48. No sample contained excessive concentrations of chromium (20 ug Cr/g foliage). Some of the higher chromium values were determined for samples collected at the control locations.

VI CHEMICAL ANALYSIS OF SOIL

A program of soil sampling in the Wawa area was carried out in conjunction with the vegetation sampling program. The sampling locations for the soil were the same as those listed for vegetation. Soil samples (0-10 cm) were collected at each location in July, 1969; on two monthly sampling trips in 1970 through 1974; and on two monthly sampling trips, in triplicate, in 1975 and 1976. The concentrations of various chemical elements considered to be excessive in soil are listed in Section V (Chemical Analysis of Vegetation).

Sulphur:

The sulphur concentrations measured in the soil samples collected in the Wawa area are presented in Table 49. Only one sample (Perry Lake, 1975) contained concentrations of sulphur greater than 0.1% S. Samples collected at the test plots usually contained higher amounts of sulphur than did samples collected at the control locations.

Iron:

The concentrations of iron in the soil samples are shown in Table 50. The highest concentrations of iron were measured at the Highway 17 and Lucy Pit locations. The iron content of the soils was quite variable from year to year at the same sites indicating that soils in the area are heterogeneous, at least with respect to iron content. Iron concentrations measured at the control locations were generally lower than at the remaining locations.

Arsenic:

Table 51 includes the data concerning arsenic in soil collected in the Wawa area. Arsenic concentrations greater than 25 ug As/g soil are considered to be excessive.

The soil samples collected at Highway 17, at Lucy Pit and all samples (except 1976), collected at Parks Lake contained excessive amounts of arsenic. The concentrations of arsenic in most of the remaining test soil samples were all elevated in relation to the control samples.

Zinc:

The zinc concentrations in the soil samples are reported in Table 52. All samples contained less zinc than the amount considered to be excessive (400 ug/g soil).

Calcium:

The concentrations of calcium present in the soil samples are shown in Table 53. Many of the reported values are low, however, there is no apparent relationship between the amount of calcium present in the soil and location of the sampling site with respect to the sintering plant. Differences in calcium concentrations between years is attributed to local variability in the soil composition.

Magnesium:

Magnesium concentrations measured in the soil samples are

reported in Table 54. The magnesium content of the soils was generally greater than the calcium content and does not show any relationship with respect to the location of the sinter plant. The small differences in magnesium content of the soils between years are attributed to local soil variability.

Soil pH:

The pH values reported for the soil samples collected in the Wawa area are presented in Table 55. The values indicate that the soils are moderately to strongly acidic (maximum pH 5.5). These low values could be partially attributed to the low calcium content of the soil. There was no apparent relationship between the soil pH and the location of the sinter plant.

VII ARSENIC STUDY - 1975

A special study to investigate the extent of dispersion and deposition of arsenic emissions from the sinter plant was completed in September 1975. Triplicate soil samples from three depths (0-5 cm, 5-10 cm and 10-15 cm) were collected at 24 sites in the Wawa area. The sites included the 10 vegetation study plots, sites in the Town of Wawa and between Wawa and Michipicoten Harbour and a number of sites to the northeast of the sinter plant. The sampling locations are shown in Figures 7 and 8 and include the following:

Site Number	Site	Location	
1	Site 1	1.1	km N
2	Site 2	2.2	km NE
3	Site 3	4.2	km NE
4	Site 4	6.3	km NE
5	Site 5	7.7	km NE
6	Site 6	10.8	km NE
7	Site 7	13.8	km NE
8	Parks Lake	16	km NE
9	Finger Lake	19	km NE
10	Perry Lake	26	km NE
11	Garbe Lake	30	km NE
12	Goudreau	35	km NE
13	Troupe Lake	40	km NE
14	Dubreuil Road	45	km NNE
15	Lucy Pit	12	km ENE
16	Hawk Junction	21	km ENE
17	Highway 17	1.6	km SW
18	Mission Road	8.0	km SSW
19	Michipicoten Harbour	9.0	km SW
20	Obatanga Park	56	km NW
21	Government Road, Wawa	0.5	km SE
22	Wawa Park	1.6	km SE
23	Beck Public School, Wawa	2.2	km SE
24	Centennial Park, Wawa	1.7	km SSE

The samples were analysed for pH and arsenic, sulphur, iron, copper, zinc, manganese, calcium and magnesium content. The results of these analyses are included in Tables 56 through 64.

Results:

The concentrations of arsenic which were measured in the soil samples are reported in Table 56. Excessive amounts (over 25 ug As/g soil) of arsenic in the upper soil horizon were found at those sites nearest to the sinter plant including Highway 17, Government Road and all the sites to the northeast up to and including Parks Lake. The concentrations of arsenic at two sites in the town of Wawa were also considered to be excessive.

Arsenic concentrations decreased with distance from the smelter, however, arsenic values were elevated at all locations in relation to the control locations at Dubreuil Road and Obatanga Park (Figure 9). The concentrations of arsenic decreased with depth of the sample. Excessive amounts of arsenic were found at 5-10 cm at Government Road, Sites 1, 2, 4, 5, Parks Lake, and Highway 17 and at 10-15 cm at Sites 1, 2 and 4.

The sulphur concentrations in the soil samples collected for the arsenic study are shown in Table 57. High concentrations of sulphur were measured in the upper 5 cm of soil at 5 of the locations (Highway 17, Government Road and Sites 1, 2 and 4) nearest to the sinter plant. High concentrations were also measured at Goudreau (5-10 cm). In general, the highest sulphur concentrations were found in upper soil horizon. The amount of sulphur in the soil samples generally decreased with increasing distance from the sinter plant.

The percent iron recorded in the soil samples is indicated in Table 58. High concentrations of iron were recorded at a number of locations. The highest reading obtained was 16.1% Fe in soil (0-5 cm) at Government Road. Elevated iron concentrations were found at all three soil depths at Highway 17, Sites 1, 2 and 3, Parks Lake and Goudreau. The high values obtained at Parks Lake and Goudreau can be explained by the fact that these sites are located in close proximity to former iron mines with high iron content in the bedrock. This could also explain the elevated level of iron (2.38%) in the lower soil horizon at Lucy Pit (a former open pit iron mine) and Finger Lake where smaller iron deposits are known. Elevated iron concentrations were also reported for soils (10-15 cm) at Sites 5 and 7. Iron tends to be leached from upper soil horizons and to accumulate in the lower horizons. It is felt that there are three dominant factors influencing the distribution of iron in the soil samples from the Wawa area. These are: 1) emissions from the sinter plant affecting site near to the sinter plant, 2) natural iron deposits and, 3) leaching of the soil profile.

The concentrations of manganese present in the soil samples are presented in Table 49. Excessive concentrations of manganese (greater than 1500 ug Mn/g soil) were recorded at Government Road, Highway 17 and Site 1. Elevated manganese concentrations were also recorded at Sites 2 and 5 and at Goudreau. The amounts of manganese decrease with distance away from the sinter plant and with increasing soil depth. The rapid decrease in manganese concentration with soil depth, especially at the sites nearest to the sinter plant, is taken

as evidence that the Mn emissions from the sinter plant are reaching the soil surface within approximately 2 km of the stack.

Zinc and copper concentrations measured in the soil samples are presented in Tables 60 and 61 respectively. The amounts of these elements are not considered excessive (zinc = 400 ug Zn/g soil; copper = 100 ug Cu/g soil) and the uniformity in concentration of these elements in the soil at all locations suggests that copper and zinc do not constitute environmental problems in the Wawa area.

The concentrations of calcium (Table 62) tend to be low, especially in the area to the northeast of the sinter plant. Calcium concentrations tend to be lower than magnesium concentrations in the same samples (Table 63). The low calcium content of the soil samples is considered to be the prime reason for the low soil pH values (Table 64). The majority of the samples were in the range pH 4.2 to pH 5.2 although samples collected at Hawk Junction, Centennial Park and Michipicoten Harbour had pH values of approximately pH 6.5. In general the pH values were lowest in the upper horizon and highest in the lowest horizon sampled.

VIII SNOW SAMPLING PROGRAM

In January 1975, a snow sampling program was carried out in the Wawa area. The results of this program have already been reported (14). A snow sampling program was also carried out in 1976. The 1976 program did not cover as great an area as the earlier program. The 8 sampling locations listed below are also shown in Figure 10.

Number	Snow Sampling Station	Location*	
1	ACR ½	0.8	km NE
2	ACR 1	1.6	km NE
3	Lucy Pit	12.0	km ENE
4	Wawa Lake	1.6	km E
5	Hawk Junction	21.3	km E
6	Government Road	0.5	km SE
7	Queens Park	1.4	km SE
8	Centennial Park	1.7	km SSE
9	Beck Public School	2.2	km SE
10	Highway 17	1.6	km SW
11	Mission Road	8.0	km SSW
12	Michipicoten Harbour	9.0	km SW
13	Control	90.0	km S

* Distance and direction from sinter plant.

At each sample location in 1976, duplicate samples of snow were collected. The sample consisted of circular cores of snow, 7.5 cm in diameter and represented a complete profile of the snow from the surface to the ground level. The sample was taken in such a manner as to avoid contamination by ground materials. The number of cores of snow required to fill 4.5 kg polyethylene bags was recorded. The samples were returned to the laboratory and allowed to melt overnight at room temperature in the polyethylene bags. The volume of snow melt-water was measured and a pH measurement taken immediately. Each sample was then divided into two equal portions and one of these portions was preserved by addition

of 2 ml of nitric acid. The acidified portion was analysed for Zn and Pb while the SO_4, Ca, Na, Cl, Mg, Fe and As concentrations and alkalinity were determined from the non-acidified portion.

Results:

The concentrations of the various chemical components of snow samples collected in the Wawa area in 1976 are shown in Table 65 together with comparable data obtained in the 1975 snow sampling program.

Iron concentrations in snow melt water samples were highest at Highway 17, ACR ½ and Government Road. These three locations are nearest to the sintering plant. Decreasing iron concentrations occurred at increasing distances from the sinter plant. The iron concentrations measured in each year were generally similar at individual locations, however, the amount of iron present in 1976 at Highway 17 (14.8 ug/ml) was considerably lower than in 1975 (99 ug/ml). The iron concentrations in snow collected at the other locations to the SW (Mission Road and Michipicoten Harbour were also lower in 1976 than 1975).

Sulphate concentrations in the snow samples collected in 1976 were lower than concentrations measured in equivalent samples collected in 1975. The greatest decrease occurred at the Highway 17 location. The majority of samples collected in the Wawa area contained elevated concentrations of sulphate in relation to the control sample.

Arsenic concentrations in the snow samples were elevated at all locations in the Wawa area (with the exception of Hawk Junction) in relation to the control samples. One sample in 1976 (ACR ½ - 95 ug/l As) and one sample in 1975 (Highway 17 - 230 ug/l As) contained arsenic in amounts equivalent to those which would exceed the maximum permissible concentration in domestic water supplies (50 ug As/l) established by the Province of Ontario. The majority of samples contained arsenic in amounts greater than the water quality objective of 10 ug As/l water. The concentrations of arsenic in general were highest in close proximity to the sinter plant and decreased with distance from this indicated source.

Lead and zinc concentrations in the snow melt water were very low indicating that there is no problem with regard to these elements in the Wawa area. Magnesium concentrations were also low.

Sodium concentrations were low at most locations except Highway 17, Michipicoten Harbour (1975) and the control site. Since elevated chloride values also occurred in the same samples, it was concluded that road salt was present in these samples. Elevated concentrations of calcium were recorded at sites in close proximity to the sinter plant (ACR ½, ACR 1, Government Road, Highway 17) and at Michipicoten Harbour. The higher calcium content of the snow samples was associated with higher alkalinity values. Higher pH values of the snow melt water from samples collected near the sinter plant were attributed to the increased particulate (including iron and calcium) present in these samples.

In summary, the snow sampling program demonstrated that airborne contaminants (sulphates, iron and arsenic) were reaching ground level and being trapped in the snow in close proximity to the sinter plant.

IX NEW VEGETATION STUDIES IN THE WAWA AREA

Data collected in the Wawa surveillance programs to the end of 1976 was reviewed. Following the review, it was concluded that a large data base had been accumulated, especially with regard to vegetation and soil samples. The surveillance program was therefore realigned in 1977, such that more specialized or more detailed projects could be carried out. The following is a brief summary of new on-going projects.

A) Revised White Birch Plots

From 1969 to 1976, 10 white birch and/or trembling aspen trees were evaluated and measured at each of the 10 permanent vegetation plots. It was decided that this number of trees was too small to adequately monitor the condition of the vegetation in one area, especially when trees could be lost to disease or pests, including beavers. In spring and early summer, 1977 the plots were enlarged and 100 healthy white birch trees were selected, tagged and measured at each plot. As far as possible, the enlarged plots encompassed the existing plots, however it was necessary to establish new plots at Dubreuil Road and Obatanga Park due to the limited number of suitable trees which were available. The Dubreuil Road plot was established approximately 200 meters north of the old plot site and consisted of semi-mature trees with a more dense canopy than the older plot.

The nearest suitable site to Obatanga Park for use in the

program was located 7 km SW of the old plot near Fungus Lake. At this location, the trees were semi-mature, had a dense canopy and were growing in shallow soil covering bedrock.

It is intended that these revised white birch study plots be maintained and the trees be evaluated and measured annually. Growth, mortality and tree crown conditions will be included in future reports prepared for the Wawa area.

B) White Pine Plots

White pine trees growing to the south and east of the fume zone northeast of Wawa had been reported to exhibit symptoms of foliar chlorosis for a number of years in the fume zone maps prepared by the Ministry of Natural Resources. In 1976, flights over this area were made by Ministry of the Environment personnel and a number of chlorotic and declining white pine trees were noted among the apparently healthy trees. In August 1976, white pine trees along the north shore of Lake Manitowik were examined and the observations made on the ground generally confirmed those made from the air.

The following conclusions were made:

1. About 10-20% of the white pine trees were dead, while 20-40% were chlorotic to some degree.

2. A limited amount of white pine blister rust was observed,

1-2% of trees.

3. No apparent pattern of decreased frequency of chlorotic trees with distance from Wawa was noted.

4. No apparent pattern with respect to age of tree.

5. No apparent pattern with respect to soil type.

6. No apparent pattern with respect to altitude or exposure.

7. Some adelgid insects and possible winter injury was present on some trees.

8. Chlorosis and some necrosis was evident on 1976 needles, while necrosis was more common on older needles.

9. Many trees had retained needles from 1974 and 1975 in addition to the current year's foliage.

10. Needles were typically short and annual growth rate, as indicated by bud scars, was low. Site may be a factor in reduced growth.

Since white pine is one of the most sensitive plant species to sulphur dioxide, and due to the proximity of the white pine stands to the fume zone, it was therefore necessary to determine if emissions from the sinter plant were involved with the injuries observed on the trees.

A program to determine the cause of the observed injuries to the white pine trees was initiated in 1977. A total of seven accessible stands of white pine were selected for study. The locations of the sites are listed below together with the distance and direction from the sinter plant.

Site	Location
Pivot Lake	27 km NE
Whitefish Lake	26 km ENE
Manitowik Lake	37 km NE
Emily Bay (Dog Lake)	56 km NE
Zajac Lake	21 km ESE
Dalton	53 km E
Shoals	65 km ESE

At each of the sites, fifty white pine trees were selected, tagged and the diameter measured. The crown condition of each tree was evaluated on a scale of 1 (healthy) to 10 (nearly dead). Overall foliage color was also evaluated by comparison with prepared color chip standards. Increment cores were taken from five trees per plot as an initial attempt to determine the age of the trees.

Soil samples were collected at each site for chemical and physical analysis as a means of determining site suitability for white pine growth. The soil at each site was a typical podzol.

As part of the white pine study, reproduction parameters of the white pine were measured. Because a "seed year" was in effect among the white pine in the Wawa area in 1977, the opportunity to carry out the reproduction study was taken in August and September. At each plot site, the number of cones on each tree was rated on a scale of + to +++++

in the following manner:

0	-	no cones
+	-	1 to 5 cones
++	-	6 to 25 cones
+++	-	25 to 100 cones
++++	-	100 to 250 cones
+++++	-	over 250 cones

As a means of determining the success of reproduction among the white pine in the area, a seed germination project was initiated. White pine cones were collected at each of thirteen sites in the Wawa area and included the seven white pine plots listed above. The additional sites included the following:

Site	Location
5 km East of Michipicoten River on Highway 101	30 km ESE
10 km East of Michipicoten River on Highway 101	39 km ESE
Lochalsh	55 km NE
* Hawk Junction	19 km ENE
* Surluga	4 km SE
Katherine Cove	63 km S

* Duplicate samples from single trees.

At each location, triplicate samples consisting of 20 cones with each sample representing one individual tree, were collected. The cones were returned to the laboratory for weighing and length and width measurement. The cones were allowed to dry on the laboratory bench in order to

facilitate removal of the seeds. At the time of writing of this report, the germination tests were not complete. A report will be prepared once the study is completed.

C) Remote Sensing Program

Fluctuation in position of the boundary lines of the different degrees of vegetation injury was observed on the fume zone maps prepared for the Wawa area by staff of the Ministry of Natural Resources. The general shape and extent of the fume zone remained similar from year to year. While it is possible that the shifting of the lines is a reflection of vegetation injury in different years, there is also a problem in that a different person might conduct the mapping each year. In order to maximize the objectivity of the mapping as well as to have a permanent record of the conditions present in 1977, it was decided that a program of remote sensing should be carried out.

In July 1977, in a co-operative program between the Ministry of Natural Resources and the Ministry of the Environment, the Ontario Centre for Remote Sensing completed a program to photograph, from the air, a portion of the fume zone. Photographs in true color, false-color infra-red and black and white were taken at an altitude of 900 m along approximately 480 km of flight lines crossing the fume zone. The information obtained in these photographs is being compared with satellite images of the area and with ground-truthing information. A report on the results of the remote sensing program will be prepared following the completion of the study.

X WAWA AREA LAKES - WATER QUALITY STUDY

A) Introduction

In 1963, Gordon and Gorham (9) identified significant sulphate (SO_4) elevations and pH reductions in lake and pond waters downwind of the Wawa sinter plant. Also, as part of a study of the chemistry of precipitation in Ontario (Kramer, 1975), bulk precipitation data (rain and dry fallout) have been collected at a location within the zone of severe vegetation damage at Wawa (see Figure 11 for station location). The table below provides deposition rates of selected parameters at the Wawa station, summarized from Kramer, 1975. For comparative purposes, data from Chapleau (100 km east of Wawa - no smelting activity) and Skead (within the Sudbury smelting area) are included in the following table.

DEPOSITION RATES (10^{-9} gm/cm^2 day) OF SELECTED PARAMETERS, WAWA FUME KILL AREA (DATA FROM CHAPLEAU AND SKEAD INCLUDED FOR COMPARISON)*

	WAWA 1/3/72 to 3/11/74		CHAPLEAU 1/3/72 to 10/10/75		SKEAD 1/6/70 to 3/11/75	
SO_4	1.2	(22)	.545	(32)	.903	(45)
Fe	306.8	(19)	54.5	(32)	113.5	(32)
Ca	404	(21)	384	(1)	253	(4)
Mg	80	(11)	130	(1)	220	(1)
Ni	.5	(18)	.6	(27)	21.9	(31)
As	.46	(1)	--		3.95	(4)
Pb	2.7	(22)	6.1	(32)	6.1	(32)
Mn	2.73	(1)	--		4.3	(8)
Cd	.17	(20)	.10	(22)	.29	(27)
Zn	33.9	(21)	19.2	(31)	23.3	(31)
Co	.13	(2)	.09	(1)	.64	(1)
Cu	.79	(20)	1.75	(30)	27.0	(32)

* samples collected on a monthly basis during period indicated. Numbers in brackets denote numbers of samples collected and analysed.

The deposition rates of sulphate, iron and zinc at Wawa exceeded values recorded at Skead, proximal to the Sudbury smelting complex. Comparison of the other parameters with data from Chapleau shows no apparent elevation at the Wawa site.

In response to concern expressed by the Ministry of Natural Resources, (M.N.R.) Wawa, regarding the water quality of area lakes, a co-operative sampling programme was carried out on 25 lakes in the Wawa area during 1971-72. Sample collections were carried out by Ministry of Natural Resources personnel and analytical services were provided by the Ministry of the Environment (M.O.E.).

During 1975, M.O.E. staff conducted further sampling of lakes in the Wawa area. Seventeen lakes, including many sampled during the 1971-72 investigation, were visited by float-equipped aircraft. Sampling was carried out according to the format devised by Conroy et al, 1974 and successfully used in the Extensive Monitoring Programme of M.O.E.'s Sudbury Environmental Study.

The Wawa area provides a unique opportunity to study the effects of atmospheric inputs from sintering activity on lake waters since southwest winds are strongly predominant during summer, resulting in a well defined zone of effect, as indicated by vegetation damage extending northeast from the sinter plant. Figure 11 is a map of the study area showing the lakes sampled. A summary of the distance and direction of the study lakes from the sinter plant is provided in the following table:

LOCATION OF THE STUDY LAKES
IN RELATION TO THE WAWA SINTER PLANT

LAKE		LAKE #	DISTANCE (km)	DIRECTION (Quadrant)
Wawa	(a)(b)	1	2	Northeast
Moran	(b)	2	3	"
Lagarde	(a)(b)	3	4	"
Arliss	(a)(b)	4	7	"
Lena	(a)	5	9	"
Mildred	(a)(b)	6	10	"
Brooks	(b)	7	12	"
Loonskin	(a)(b)	8	13	"
Bauldry	(b)	9	14	"
Garbe	(b)	10	15	"
Goetz	(a)(b)	11	16	"
West Andre	(b)	12	17	"
Hawk	(a)(b)	13	18	"
Parks	(b)	14	18	"
Andre	(a)(b)	15	19	"
Finger	(a)	16	23	"
Wallace	(b)	17	24	"
Perry	(a)(b)	18	26	"
Pivot	(b)	19	27	"
Selkirk	(b)	20	28	"
Billboy	(a)(b)	21	32	"
Summit	(a)	22	35	"
Morrison	(b)	23	36	"
Troupe	(b)	24	36	"
Herman	(a)	25	38	"
Maskinonge	(b)	26	42	"
Swanson	(b)	27	43	"
Dog	(a)	28	55	"
Black Trout	(a)	29	5	Northwest
Catfish	(a)	30	9	"
Clearview	(v)	31	22	"
Goldie	(b)	32	36	"

(a) Sampled by M.O.E., 1975

(b) Sampled by M.N.R., 1971-72

The Wawa area is located within the Precambrian Shield region of Ontario. Local geology is composed of Precambrian age volcanic rocks overlain by unconsolidated deposits of glacial-fluvial material varying locally from a thin veneer to a considerable depth. Significant sulphide mineralization, predominantly pentlandite ($FeNi_9S_8$), chalcopyrite ($CuFeS_2$), and pyrite (FeS_2) as well as arsenopyrites occurs in association with metasediments. The ore mined and subsequently processed at Wawa is composed mainly of the mineral siderite ($FeCO_3$) although sufficient pyritic minerals are present to result in significant sulphur dioxide (SO_2) emissions from the sinter plant as outlined in Section II of this report.

B) Chemical Analysis of Lake Waters

i) General Water Chemistry

The results of selected chemical analyses are provided in Tables 66 and 67 for 1971-72 and 1975 respectively. A summary of ranges in concentration for the data is provided in the following table:

RANGE IN WATER-BORNE CONCENTRATIONS OF SELECTED PARAMETERS, WAWA AREA STUDY LAKES, 1971-72 AND 1975.

PARAMETER	RANGE	
	EXPERIMENTAL LAKES (Northeast Quadrant)	REFERENCE LAKES (Northwest Quadrant)
pH	3.4 - 8.0	6.9 - 7.6
Cond. (umhos/cm)	45 - 300 (15)	47 - 89 (2)
Alk. (mg/l)	0 - 48	9 - 21
Hard. (mg/l)	16 - 296	18 - 32
Ca (mg/l)	6 - 36	5.5 - 10.5
Mg (mg/l)	< 1 - 50	< 1 - 1.4
Na (mg/l)	.3 - 3	.6 - 1.6
SiO_2 (mg/l)	.2 - 1.1	.4 - .7
SO4 (mg/l)	9 - 227	8 - 14
Cl (mg/l)	.2 - 6.4	.4 - 2.5

Number of samples is 37 for experimental lakes and 4 for reference lakes respectively except where number of samples is indicated in brackets.

As indicated above, concentrations of chemical constituents showed wide variation between the study lakes. In general, pH ranged from slightly acidic to slightly basic and conductivity, alkalinity and hardness were relatively high for lakes on the Precambrian Shield. Lagarde Lake (4 km northeast of the sinter plant) was a notable exception, exhibiting extremely low pH (3.4 - 3.5) and virtually no alkalinity.

Figure 12 depicts the distribution of pH, hardness, conductivity and alkalinity in the study lakes as a function of distance northeast of the sinter plant. As shown in Figure 12a, no relationship between lake-water pH and sintering activity was apparent, however, alkalinity, hardness and conductivity (Figures 12b, 12c and 12d respectively) tended to increase with increasing proximity to the sinter plant - although considerable scatter is evident in the data plots. Comparison of the experimental data with values for the reference lakes indicate elevations in hardness, alkalinity and to a lesser extent conductivity extending 30 - 40 km northeast of the sinter plant.

As reflected by the relatively high hardness, alkalinity and conductivity, most major ions were relatively abundant in the study lakes.

Calcium was the major cation, followed in predominance by magnesium, sodium and potassium. Concentrations of calcium (Figure 13a) and magnesium (Figure 13b) bore an inverse relationship to distance from the sinter plant. Calcium and magnesium values exceeding those in the reference lakes were recorded to a distance of ~40 km from the sinter plant. Concentrations of sodium and potassium also exhibited a tendency to decrease

with distance from the sinter plant, however, with the exception of a few high values in lakes relatively close to the emission source (0 - 20 km) concentrations were within the range recorded in the reference lakes (Figure 13c and 13d).

Concentrations of sulphate, the major anion in the study lakes (see Figure 14b) correlated well with distance from the sinter plant while concentrations of silica showed no relationship to sintering activity (Figure 14a). Concentrations of chloride (Figure 14c) exceeding values in the reference lakes were recorded to a distance of 20 km northeast, however, most lakes, even those proximal to the sinter plant, had low concentrations.

ii) Heavy Metals

The results of heavy metals analyses are provided in Table 68. Concentations of heavy metals in the study lakes were generally low, in most cases below the detection limit employed in the analyses.

Water-borne concentrations of cadmium were uniformly < 1 ug/l and with the exception of Lagarde Lake which exhibited approximately two fold elevations, concentrations of copper, nickel and lead were consistently < 3 ug/l. Concentrations of zinc in most cases were < 3 ug/l, however, a significant elevation (62 ug/l) was recorded in Lagarde Lake and lesser elevations were found in Hawk, Summit and Herman lakes (6, 16 and 18 ug/l respectively). These apparent elevations over background concentrations showed no obvious relationship to sintering activity.

Concentrations of iron in the study lakes showed wide variation (7 to 100 ug/l) however as with zinc, no pattern associated with sintering activity was evident.

Arsenic was the only element, of those measured in the aqueous phase in the study lakes, which exhibited an apparent relationship to sintering activity. Figure 15 shows the distribution of arsenic concentrations in the surface waters of the study lakes. From the figure, a zone of measurably elevated water-borne arsenic concentrations extending northeast from the sinter plant is evident.

C) Analyses of Lake Sediments

The results of analyses of lake sediments (only 1975 data available) are provided in Table 69. Plots of concentrations of selected parameters versus distance northeast of the sinter plant are depicted in Figures 16 to 18.

As shown in Figures 16 and 17, sediment-borne concentrations of cadmium, iron, arsenic, zinc, copper, nickel and lead bore significant relationships to sintering activity. Generally, metal concentrations proximal to the sinter plant (< 5 km) were low, however elevations occurred between 10 and 30 km for zinc, copper, lead, and cadmium and between 10 and 20 km for nickel, arsenic and iron. It is interesting to note, however, that many of the zinc, nickel, and iron concentrations in lakes northeast of the sinter plant were considerably lower than those recorded in the reference lakes.

Concentrations of nitrogen and phosphorus and values for loss on ignition (Figure 18) show distributions similar to those observed for heavy metals. Significant increases in these parameters occurred between 10 and 40 km northeast of the sinter plant.

D) Discussion

In recent years, the influence of the atmosphere on lake waters has received increasing attention. Adverse effects on water quality resulting from atmospherically conveyed inputs of contaminants have been documented, and major programmes to evaluate the significance of atmospheric inputs have been mounted in the U.S.A., Canada and Scandinavia.

In the Sudbury area of Ontario, atmospherically conveyed contaminants originating from smelting activity have resulted in elimination of natural fish populations (2) and significant alteration in the abundance and community structure of other aquatic biological populations (4).

Two major problems associated with atmospheric inputs to lake waters are: acidification and heavy metal deposition. These topics are discussed below in context of the Wawa, Ontario area.

i) Acidification

In areas of sulphide mineralization, such as Wawa, the smelting of ores results in the liberation of large quantities of sulphur dioxide to the atmosphere. Through the mechanisms

of washout and fallout, sufficient quantities of sulphuric acid (the product of oxidation and hydrolysis of sulphur dioxide) can become available in surface waters to cause pH depression. Relatively small quantities of sulphuric acid are sufficient to cause significant pH reductions (H^+ elevations) in lakes with poor natural buffering capacity (ability to neutralize acid). Since metal recovery activities are often conducted in areas where the geology is such that the buffering capacity of lakes is inherently low, it is relatively easy to cause damage over great distances.

In addition to the direct lethal and sublethal effects on biota of low pH, studies have shown that metal solubility increases as pH decreases. Since smelting activities have been shown to cause both heavy metal elevations and pH reduction, the toxicity potential of this combined effect is of extreme concern in areas receiving significant atmospheric inputs.

Based on the data presented, atmospherically induced acidification is not occurring in the study lakes. These findings are inconsistent with those reported by Gordon and Gorham, 1963 (9), for the same area. In that study, the authors found a significant decrease in the pH of lake and pond waters to a distance of ∿10 km northeast of the sinter plant. The discrepancy between the results of these investigations (see Figure 19) may be due to the bias of the present study toward the larger lakes in the area (suitable for float-equipped aircraft). The smaller lakes and ponds sampled by Gordon and Gorham may be more susceptible to acidification, and indeed may still exhibit the problem. During the present

study, the only Lake showing a seriously depressed pH was Lagarde (3.4 to 3.5). The low pH of Lagarde Lake may reflect a very limited supply of buffering species to the lake due to local geology highly resistant to weathering. Accessory data indicate a very low pH ($\sim$ 3.8) in at least one other area lake (Blueberry).

Although pH depression was not apparent in the study lakes, elevated waterborne concentrations of sulphate, bearing a direct relationship to sintering activity were recorded. The sulphate data are in essential agreement with that of Gordon and Gorham, 1963, (see Figure 20). On the basis of the above, it appears that the study lakes have sufficient buffering capacity to effectively neutralize present acidic inputs from the atmosphere.

When considering the significance of buffering agents in the study lakes, it is important to note the general distribution pattern observed for most major cations measured i.e.: an elevation, to some degree, in the area northeast of the sinter plant. Gordon and Gorham, 1963, reported a similar increase for calcium concentrations, tentatively attributing it to weathering action on soils and rocks within the "Fume Kill Area" by sulphuric acid.

Such leaching phenomena take the form of ion exchange reactions where H^+ is exchanged for cations. The decomposition of the feldspar anorthite, and limestone, in soil weathering reactions are examples:

$$CaAl_2SiO_2 + H_20 + 2H^+ = Al_2Si_2O_8\ (OH)_4 + Ca^{++}$$

$$CaCO_3 + H^+ = Ca^{++} + HCO_3^-$$

In the above reactions, Ca^{++} and HCO_3^- will be soluble and available for transport to the aquatic system.

Sodium enrichment of lake waters could occur from the same reaction involving albite, the sodium rich end member of the plagioclase feldspars. According to Hem (10), the normal composition of the plagioclase feldspars lies between the pure calcium and sodium end members and decomposition will generally yield both calcium and sodium. Owing to the natural abundance of silica, it is normal that weathering reactions involving cation silicates will solubilize quantities of silica as well as calcium and sodium.

From the point of view of protecting a lake from acidification, it is important that sufficient minerals such as feldspars and/or limestone are present in the drainage basin in a form that would allow the reactions described above to proceed. These will act as a H^+ sink and retard pH depression in the water. From a sulphuric acid soil reaction, cations such as calcium, magnesium and sodium and the anion sulphate would be expected to increase in the aquatic system while pH would remain unchanged. As indicated previously, distributions of major cations (Figure 13), sulphate (Figure 14b) and pH (Figure 12a) in the study lakes conform to this pattern.

An alternate, or perhaps additional source of calcium and other ions to the study lakes may be direct deposition. The bulk precipitation data presented (12) do not show elevated deposition rates of cations, however the sampling station used (see Figure 11) does not appear to fall within the apparent "major deposition zone" as indicated by plots of lake water concentrations (Figures 12 to 14). Since

carbonate ores such as that ($FeCO_3$) smelted at Wawa may contain quantities of magnesium, calcium, sodium and potassium, significant amounts of these ions may be released to the atmosphere and subsequently become available to lake waters. Further, significant quantities of calcium carbonate ($\sim$50 tons/hr) are used as feed in the sintering process, likely resulting in large calcium emissions. It is significant to note that lake water concentrations of silica (not abundant in carbonate ores) did not show a meaningful relationship to distance from the sinter plant. Unfortunately, no reliable emissions data are available to shed additional light on this theory.

An additional, basic alternative to the "weathering" and "deposition" hypotheses is that the elevations of major ions observed may be attributable, at least in some degree, to naturally more abundant, very local, lithological sources.

Of major significance in the consideration of influences of smelting activity on the study lakes is the evaluation of projected effects likely to occur with continued loadings. Conroy et al, (3) defined a calcite saturation index (CSI) to predict lakes with low pH, lakes susceptible to pH depression and lakes with sufficent buffering to provide protection against pH depression from atmospheric fallout. The CSI is defined by:

$CSI = -\log_{10} (IAP) + \log_{10} (K_{CaCO_3})$ where IAP is the ion activity product for calcium carbonate ($CaCO_3$) and is calculated by:

$$IAP = \frac{(Ca)\ K_2\ (Alk)}{40{,}000\ (H)}$$

where Ca is the calcium ion (Ca^{++}) concentration in

mg/l, K_2 is the second dissociation constant for carbonic acid, Alk is the alkalinity in eq/l and H is the hydrogen ion (H^+) concentration (eq/l).

The resulting CSI is positive for lakes of low H^+ assimilation and approaches zero for saturation with respect to $CaCO_3$.

CSI values of >5 represent lakes with pH <5.0 and no assimilation capacity for H^+. Lakes with CSI's of 4 and possibly 3 may be susceptible to acidification with continued loadings and lakes with CSI's of <3 appear able to effectively neutralize continuing inputs of H^+. The following table summarizes the CSI values of the study lakes:

CSI's, WAWA AREA STUDY LAKES

LAKE	#	CSI	LAKE	#	CSI
Wawa	1	1.7	Perry	18	1.8
Moran	2	1.1	Pivot	19	2.7
Lagarde	3	6.9	Selkirk	20	1.2
Arliss	4	1.7	Billboy	21	2.2
Lena	5	1.4	Summit	22	1.8
Mildred	6	1.2	Morrison	23	1.5
Brooks	7	.2	Troupe	24	2.3
Loonskin	8	2.1	Herman	25	1.4
Bauldry	9	2.3	Maskinonge	26	2.1
Garbe	10	1.6	Swanson	27	3.1
Goetz	11	1.2	Dog	28	1.5
West Andre	12	1.0	Black Trout	29	4.0
Hawk	13	1.5	Catfish	30	1.9
Parks	14	1.4	Clearview	31	2.3
Andre	15	1.0	Goldie	32	1.7
Finger	16	2.4			
Wallace	17	.6			

Based on the data provided, the study lakes appear well able to absorb without effect, acidic, atmospheric loadings. Lagarde was the only lake exhibiting a critical CSI (6.9) and only two lakes - Black Trout (reference) and Swanson had CSI's (3.1 and 4.0) indicating possible susceptibility to future H^+ inputs.

ii) Heavy Metals Deposition

Atmospherically conveyed inputs of heavy metals to lake waters are of major concern due to the proven toxic and/or inhibitory effects of elevated metal concentrations on aquatic biota.

As previously indicated, based on the present data, water-borne concentrations of most heavy metals in the study lakes, including cadmium, copper, nickel, iron and lead did not bear any obvious relationship to sintering activity. The only water-borne heavy metal demonstrating a significant correlation with distance from the sinter plant was arsenic, which exhibited a measurable elevation in lakes northeast of the sinter plant to a distance of 30 km. It should be noted that although an elevation in lake water concentrations of arsenic due to atmospheric inputs was evident, concentrations remained very low. The maximum recorded arsenic concentration in the study lakes (9 ug/l) is well within the suggested guidelines for protection of fish and aquatic life (1000 ug/l) and domestic water supplies (50 ug/l - EPA)(7).

Concentrations of heavy metals in lake sediments bore a direct relationship to distance from the sinter plant - unlike the lack of definition observed in lake waters. As depicted in Figure 21 for arsenic, somewhat similar patterns have been reported for As concentrations in soils (see Section VII - Arsenic Study).

Semkin and Kramer, (17) provide data for heavy metal concentrations in the bottom sediments of 66 lakes in the

Sudbury, Ontario, region. The table below provides a summary of their data and compares it to data from the present study.

COMPARISON OF HEAVY METAL CONCENTRATIONS IN THE SEDIMENTS OF WAWA AREA LAKES AND SUDBURY AREA LAKES.

ELEMENT	SUDBURY LAKES (66)		WAWA LAKES (16)	
	Range	Mean	Range	Mean
Ni (ug/g)	30-630	120	14-110	36
Cd (ug/g)	.5-19.4	8.6	.5-4.2	2.1
Pb (ug/g)	34-290	116	3-130	66
Cu (ug/g)	37-515	101	18-100	54
Zn (ug/g)	46-270	152	97-360	163
Fe (mg/g)	5.2-134	32	13.5-190	46

As shown in above, the mean sediment-borne zinc and iron concentrations in the Wawa lakes exceeded those reported for Sudbury area lakes - showing agreement with the comparative deposition data provided previously. Although sediment concentrations of nickel, cadmium, lead and copper exhibited elevations northeast of the Wawa sinter plant, comparison of the data with the results of Semkin and Kramer indicate that these elevations are not extreme. Maximum concentrations of nickel, cadmium, lead and copper in the sediments of Wawa lakes were consistently lower than, or only slightly exceeded, mean concentrations of these metals in Sudbury area lakes.

In evaluating the significance of heavy metals in the study lakes, the parallel distribution patterns observed for heavy metals, nitrogen, phosphorus and loss on ignition in sediments are of interest, but remain unexplained at this time.

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XIII APPENDIX

A) Vegetation Plot Locations & Site Descriptions**

Highway 17

Location:

On the north bank of Magpie River, approximately 1.6 km SW of A.O.D. sinter plant.

Site Description:

This plot is located on a well drained site. The area is covered with a semi-mature stand on white birch, trembling aspen and white spruce. Speckled alder, mountain maple and prairie willow are common shrubs in the understory. The ground cover vegetation consists of a large number of grasses and herbaceous plants.

Lucy Pit

Location:

Approximately 10 km ENE of the sinter plant on the southern edge of the "Total Kill" section of the fume damage area.

Site Description:

The area is well drained with a shallow soil profile and many rock outcrops. The dominant tree species is small white birch with scattered trembling aspen, showy mountain ash and mountain maple. The ground cover vegetation is composed of a variety of plant

species with grasses and blueberry predominating.

Parks Lake

Location:

Approximately 16 km NE of the sinter plant on the south edge of the "Total Kill" section of the fume damage area. The plot site at the west end of the lake escaped the fires of 1963 and 1976.

Site Description:

Soil profile shallow and well drained with several rock outcrops. The area is open and sparsely covered with small white birch, alder, and mountain maple. The ground cover vegetation is composed mainly of grasses, blueberry and large-leaved aster.

Finger Lake

Location:

Approximately 19 km NE of the sinter plant on the north edge of the "Total Kill" section of the fume damage area.

Site Description:

An open well-drained site with shallow soil profile and common rock outcrops. The site is sparsely covered with small white birch,

showy mountain ash and mountain maple. Blueberry and large-leaved aster are the predominant ground cover species.

Perry Lake

Location:

On the south side of the lake approximately 26 km NE of the sinter plant in the "Heavy Kill" section of the fume damage area.

Site Description:

A poorly drained site with organic soil. White birch, alder, mountain maple and showy mountain ash are the dominant plant species. Blueberry is the dominant ground cover species.

Garbe Lake

Location:

Approximately 30 km northeast of the sinter plant in the "Heavy Kill" section of the fume damage area.

Site Description:

A well-drained site with a shallow soil profile. The area is covered with a semi-mature stand of white birch and white spruce. The dominant ground cover species are blueberry, large-leaved aster and bunchberry.

Goudreau

Location:

Approximately 35 km NE of the sinter plant in the "Light Damage" section of the fume damage area.

Site Description:

A well-drained site with a southern exposure. The soil profile is very shallow with common rock outcrops. The area is moderately covered with semi-mature white birch, trembling aspen and jack pine. Large-leaved aster and grasses are the dominant ground cover species.

Troupe Lake

Location:

This plot is located on the NW side of the lake approximately 40 km NE of the sinter plant in the "Light Damage" section of the fume damage area.

Site Description:

A well-drained rocky site with a shallow soil profile. The area covered with a semi-mature stand of trembling aspen, white birch, white spruce and alder. The dominant ground plants are large-leaved aster and Diervilla lonicera.

Dubreuil Road

Location:

A control location approximately 45 km NE of the sinter plant.

Site Description:

A well-drained, very sandy soil. The site is open with small white birch, trembling aspen, jack pine, white spruce and alder. Blueberry, bracken fern and Aralia are the dominant ground cover plant species.

Obatanga Park

Location:

A control location approximately 56 km NW of the sinter plant.

Site Description:

A poorly drained site, covered with a mature stand of white birch, trembling aspen, black spruce and balsam fir. The dense tree canopy prevents the development of a thick ground cover.

** The terms "Total Kill", "Heavy Damage" and "Light Damage" are the terms used by personnel from the Ministry of Natural Resources at Wawa to describe the zones of the three types of injury mapped by air in the Wawa fume damage area for the past several years.

Table 1

SUMMARY OF SO_2 DATA COLLECTED AT THE HILLCREST AVENUE STATION IN WAWA DURING 1976

Month	No. of Hourly Readings	Monthly Avg.(ppm)	Max. 1 Hr. Conc.(ppm)	Max. 24 Hr. Conc.(ppm)	No. of Times Above Provincial Criterion 1 Hr*	24 Hr**
January	727	.033	1.64	.27	20	3
February	674	.047	2.20	.33	27	4
March	727	.006	0.37	.08	7	0
April	168	.018	0.64	.03	3	0
May	579	.008	1.13	.06	3	0
June	663	.004	0.72	.13	3	1
July	734	.005	0.34	.03	2	0
August	489	.001	0.57	.02	1	0
September	694	.008	0.82	.12	6	1
October	739	.018	2.12	.15	16	2
November	717	.012	0.56	.12	13	1
December	658	.011	0.65	.07	10	0
Total	7569	Mean .014	Max. 2.20	Max. .33	Totals 111	12

* Ontario Criterion: 0.25 ppm

** Ontario Criterion: 0.10 ppm

Table 2

SUMMARY OF SO_2 DATA COLLECTED AT THE HILLCREST AVENUE STATION IN WAWA DURING 1977

Month	No. of Hourly Readings	Monthly Avg.(ppm)	Max. 1 Hr. Conc.(ppm)	Max. 24 Hr. Conc.(ppm)	No. of Times Above Provincial Criterion 1 Hr*	24 Hr**
January	735	.018	1.30	.09	15	0
February	660	.007	0.56	.07	5	0
March	737	.008	1.37	.15	7	1
April	709	.005	0.19	.05	0	0
May	700	.001	0.26	.01	1	0
June	717	.003	0.23	.03	0	0
July	736	.003	0.52	.03	1	0
August	730	.004	0.43	.04	2	0
September	465	.003	1.06	.05	1	0
October	728	.026	1.76	.26	24	2
November	650	.024	1.90	.26	16	3
December	714	.011	1.75	.08	5	0
	Total 8281	Mean .010	Max. 1.90	Max. .26	Totals 77	6

* Ontario Criterion: 0.25 ppm

** Ontario Criterion: 0.10 ppm

Table 3

SUMMARY OF SO_2 DATA COLLECTED AT THE GOUDREAU STATION DURING 1976

Month	No. of Hourly Readings	Monthly Avg.(ppm)	Max. 1 Hr. Conc.(ppm)	Max. 24 Hr. Conc.(ppm)	No. of Times Above Provincial Criterion 1 Hr*	24 Hr**
May	109	.013	0.26	.02	1	0
June	436	.025	0.42	.11	7	2
July	489	.018	0.33	.07	2	0
August	612	.049	0.67	.20	37	4
September	447	.033	0.60	.14	14	1
October	317	.018	0.14	.03	0	0
	Total 2410	Mean .030	Max. 0.67	Max. .20	Totals 61	7

* Ontario Criterion: 0.25 ppm

** Ontario Criterion: 0.10 ppm

SUMMARY OF SO_2 DATA COLLECTED AT THE GOUDREAU STATION DURING 1977

Month	No. of Hourly Readings	Monthly Avg.(ppm)	Max. 1 Hr. Conc.(ppm)	Max. 24 Hr. Conc.(ppm)	No. of Times Above Provincial Criterion 1 Hr*	24 Hr**
May	307	.023	0.59	.08	2	0
June	688	.020	0.45	.09	6	0
July	733	.023	0.47	.15	7	1
August	737	.013	0.27	.06	1	0
September	295	.004	0.18	.03	0	0
October	416	.004	0.32	.03	1	0
	Total 3176	Mean .016	Max. 0.59	Max. .15	Totals 17	1

* Ontario Criterion: 0.25 ppm

** Ontario Criterion: 0.10 ppm

Table 5

MONTHLY GROUP FREQUENCY DISTRIBUTION OF THE SO_2 DATA
COLLECTED AT THE HILLCREST AVENUE STATION IN WAWA DURING 1976

Month	0-.10	.11-.25	.26-.50	.51-.99	≥1.00 ppm	Total
January	692	15	8	7	5	727
February	628	19	9	8	10	674
March	712	8	7	0	0	727
April	161	4	2	1	0	168
May	570	6	1	1	1	579
June	658	2	1	2	0	663
July	728	4	2	0	0	734
August	488	0	0	1	0	489
September	675	13	4	2	0	694
October	710	13	13	2	1	739
November	687	17	11	2	0	717
December	641	7	6	4	0	658
TOTAL	7350	108	64	30	17	7569

Table 6

MONTHLY GROUP FREQUENCY DISTRIBUTION OF THE SO_2 DATA
COLLECTED AT THE HILLCREST AVENUE STATION IN WAWA DURING 1977

Month	0-.10	.11-.25	.26-.50	.51-.99	≥1.00 ppm	Total
January	700	20	11	3	1	735
February	644	11	4	1	0	660
March	726	4	4	2	1	737
April	704	5	0	0	0	709
May	699	0	1	0	0	700
June	713	4	0	0	0	717
July	732	3	0	1	0	736
August	721	7	2	0	0	730
September	462	2	0	0	1	465
October	696	8	12	9	3	728
November	626	8	4	9	3	650
December	695	14	3	1	1	714
TOTAL	8118	86	41	26	10	8281

Table 7

SEASONAL VARIATION IN SO_2 LEVELS AT THE HILLCREST AVENUE STATION IN WAWA IN 1976 AND 1977

Season	Year	Average SO_2 Conc.(ppm)		No. of Times Above Provincial Criterion 1Hr	24Hr
Winter	1976	.029		54	7
	1977	.011		27	1
			Total	81	8
Spring	1976	.010		9	1
	1977	.003		1	0
			Total	10	1
Summer	1976	.005		9	1
	1977	.003		4	0
			Total	13	1
Fall	1976	.014		39	3
	1977	.020		45	5
			Total	84	8

Table 8

MONTHLY GROUP FREQUENCY DISTRIBUTION OF THE SO_2
DATA COLLECTED AT THE GOUDREAU STATION DURING 1976

Month	0-.10	.11-.25	.26-.50	.51-.99	≥1.00 ppm	Total
May	107	1	1	0	0	109
June	397	32	7	0	0	436
July	460	27	2	0	0	489
August	525	50	31	6	0	612
September	418	15	13	1	0	447
October	316	1	0	0	0	317
TOTAL	2223	126	54	7	0	2410

Table 9

MONTHLY GROUP FREQUENCY DISTRIBUTION OF THE SO_2
DATA COLLECTED AT THE GOUDREAU STATION DURING 1977

Month	0-.10	.11-.25	.26-.50	.51-.99	≥1.00 ppm	Total
May	286	19	1	1	0	307
June	647	35	6	0	0	688
July	672	54	7	0	0	733
August	711	25	1	0	0	737
September	293	2	0	0	0	295
October	413	2	1	0	0	416
TOTAL	3022	137	16	1	0	3176

Table 10

SULPHATION RATES ON LEAD PEROXIDE CANDLES DURING THE SUMMER OF 1976 IN THE WAWA AREA (mg SO_3/100 cm^2/day)

Plot No.	Location	Distance & Direction From Sinter Plant	Mid April to Mid May	Mid May to Mid June	Mid June to Mid July	Mid July to Mid August	Mid August to Mid Sept.	Mean
1	Highway 17	1.6 km SW	0.61	0.32	0.81	0.08	0.60	0.48
2	Lucy Pit	10 km NE	1.31	1.84	1.66	1.63	1.63	1.64
3	Parks Lake	16 km NE	-	1.02	2.59	2.11	1.20	1.73
4	Finger Lake	19 km NE	0.90	0.42	1.08	0.74	-	0.78
5	Perry Lake	26 km NE	0.53	0.14	0.37	0.50	0.22	0.35
6	Garbe Lake	30 km NE	0.55	0.13	0.48	0.72	0.32	0.44
7	Goudreau	35 km NE	0.34	0.12	0.21	0.56	0.17	0.28
8	Troupe Lake	40 km NE	0.41	0.16	0.29	-	0.19	0.26
9	Dubreuil Road	45 km NNE	0.10	N.D.	N.D.	0.05	0.05	0.04
10	Obatanga Park	56 km NE	0.04	N.D.	N.D..	0.02	0.03	0.02
							Overall Mean	0.58

M.O.E. Criterion for Sulphation Rate: 0.70 mg SO_3/100 cm^2/day for a 30 day period.

Table 11

SULPHATION RATES ON LEAD PEROXIDE PLATES DURING THE SUMMER OF 1977 IN THE WAWA AREA (mg SO_3/100 cm^2/day)

Plot No.	Location	Distance & Direction From Sinter Plant	Mid April to Mid May	Mid May to Mid June	Mid June to Mid July	Mid July to Mid August	Mid August to Mid Sept.	Mean
1	Highway 17	1.6 km SW	0.75	0.32	0.08	1.26	0.11	0.50
2	Lucy Pit	10 km NE	1.42	4.07	4.54	2.24	0.22	2.49
3	Parks Lake	16 km NE	1.20	3.28	4.86	N.D.	1.59	2.19
4	Finger Lake	19 km NE	0.84	1.78	1.86	0.42	-	1.22
5	Perry Lake	26 km NE	0.62	0.95	0.74	0.18	0.16	0.53
6	Garbe Lake	30 km NE	0.56	0.65	0.69	0.27	0.13	0.46
7	Goudreau	35 km NE	0.29	0.51	0.58	0.14	0.11	0.33
8	Troupe Lake	40 km NE	0.33	0.76	0.54	0.21	-	0.46
9	Dubreuil Road	45 km NNE	-	-	0.11	0.08	0.03	0.07
10	Obatanga Park	56 km NE	-	-	N.D.	0.08	0.14	0.07
							Overall Mean	0.94

M.O.E. Criterion for Sulphation Rate: 0.70 mg SO_3/100 cm^2/day for a 30 day period.

Table 12

TOTAL SUSPENDED PARTICULATE LEVELS
MEASURED AT THE CHURCHILL AVE. - MISSION RD.
SITE IN WAWA (1976)

Date	TSP (ug/m^3)
January 25	1
28	21
February 3	48
9	26
12	27
15	17
18	25
21	16
24	19
27	14
March 1	14
4	17
7	26
10	16
13	13
16	185
19	52
22	31
25	18
31	67
April 6	107
12	40
24	51
30	29
May 6	48
12	107
June 17	52
23	109
29	45
July 5	193
17	71
23	100
29	47
August 4	29
10	83
16	32
22	114
Sept. 3	32
9	87
15	101
21	46
27	42
October 3	81
9	13

Table 13

TOTAL SUSPENDED PARTICULATE LEVELS
MEASURED AT THE HILLCREST AVE. STATION
IN WAWA IN 1976

Date		TSP (ug/m^3)
April	24	14
	11	30
May	6	32
	12	49
	18	9
	24	9
	30	58
June	5	51
	11	30
	17	20
	23	90
	29	29
July	5	41
	16	28
	23	14
	29	14
August	4	43
	10	44
	16	38
	22	106
	28	27
Sept.	3	31
	9	73
	15	37
	21	55
	27	15
October	15	19
	21	17
	27	27
November	2	38
	8	22
	14	18
	20	62
	26	52
December	2	21
	8	64
	14	19

Table 14

TOTAL SUSPENDED PARTICULATE LEVELS
MEASURED AT THE HILLCREST AVE. STATION
IN WAWA IN 1977

Date		TSP (ug/m^3)
January	19	63
	25	23
February	6	18
	12	30
	18	62
March	8	35
	14	13
	20	65
	26	34
August	5	15
	11	35
	17	16
	23	27
Sept.	4	14
	10	31
	16	21
	22	35
	28	30
October	4	20
	10	21
December	3	24
	9	20
	15	20
	21	31
	27	25

ELEMENTAL ANALYSIS OF HI-VOL FITERS EXPOSED
AT THE HILLCREST AVE. STATION IN WAWA IN 1976 AND 1977

Element	No. of Samples Analyzed		Maximum Value (ug/m^3)		Mean Value (ug/m^3)		Provincial 24 Hour Criterion (ug/m^3)
	1976	1977	1976	1977	1976	1977	
Fe	27	26	13.0	6.5	3.4	2.2	No criterion
Pb	27	26	0.6	0.5	0.1	0.1	5
Mn	27	26	0.8	0.4	0.2	0.1	50
Zn	27	22	0.2	0.1	0.01	0.01	No criterion

Table 16

POTENTIALLY INJURIOUS FUMIGATIONS RECORDED BY WAWA AREA SO_2 MONITORS IN 1976 and 1977

LOCATION	YEAR	NUMBER OF PIF	DATE	INTENSITY
Wawa	1976	3	May 9	119
			June 15	143
			October 13	122
Wawa	1977	2	September 28	111
			October 10	261
Goudreau	1976	0	September 17	84
Goudreau	1977	0	July 27	86

Table 17

SEVERITY OF OBSERVED SO_2 INJURY TO VEGETATION AT SURVEILLANCE PLOTS IN THE WAWA AREA DURING 1976

Plot	May*	June	July	August
Highway 17	-	none	moderate	moderate
Lucy Pit	-	light-moderate	severe	severe
Parks Lake	-	light-moderate	severe	severe
Finger Lake	-	none	none	moderate-severe
Perry Lake	-	none	none	trace
Goudreau	-	none	none	none
Garbe Lake	-	none	none	trace
Troupe Lake	-	none	none	none
Dubreuilville Road	-	none	none	none
Obatanga	-	none	none	none

* Trees not in leaf.

Table 18

SEVERITY OF OBSERVED SO_2 INJURY TO VEGETATION AT SURVEILLANCE PLOTS IN THE WAWA AREA DURING 1977

Plot	May*	June	July	August
Highway 17	-	light	light	light
Lucy Pit	-	moderate	severe	severe
Parks Lake	-	light	moderate-severe	severe
Finger Lake	-	light	severe	severe
Perry Lake	-	light	light	light
Goudreau	-	light	light	light
Garbe Lake	-	trace	light	light
Troupe Lake	-	none	none	none
Dubreuilville Road	-	none	none	none
Obatanga	-	none	none	none

* Trees not in leaf.

Table 19

DISTRIBUTION OF TREE CROWN CLASSIFICATIONS
EVALUATED AT WAWA AREA VEGETATION PLOTS
IN AUGUST, 1975

PLOT	YEARS*	Crown Classification 1	2	3	4	Dead
Highway 17	2	10	0	0	0	0
Lucy Pit	3	10	0	0	0	0
Parks Lake	8	4	0	2	2	2
Finger Lake	8	4	0	4	1	1
Perry Lake	8	4	0	1	2	3**
Garbe Lake	8	7	0	1	2	0
Goudreau	8	8	0	2	0	0
Troupe Lake	3	10	0	0	0	0
Dubreuil Road	3	10	0	0	0	0
Obatanga Park	8	9	0	0	0	1

* Numbers of years of observation

** Trees lost through beaver activity

Table 20

DISTRIBUTION OF SHRUBS CROWN CLASSIFICATIONS
EVALUATED AT WAWA AREA VEGETATION PLOTS
IN AUGUST, 1976

PLOT	YEARS*	Crown Classification 1	2	3	4	Dead
Highway 17**	2	8	2	0	0	0
Lucy Pit	3	7	0	1	2	0
Parks Lake	8	3	0	3	2	2
Finger Lake**	8	2	0	1	4	3
Perry Lake	8	2	0	1	1	6
Garbe Lake	8	9	0	0	1	0
Goudreau	8	7	0	1	0	2
Troupe Lake	3	10	0	0	0	0
Dubreuil Road	3	8	0	0	1	1
Obatanga Park	8	5	0	0	4	1

* Numbers of years of observation

** Values are for 1975 observations.

Table 21

PLANT SPECIES RECORDED AT THE VEGETATION PLOTS

IN THE WAWA AREA

COMMON AND SCIENTIFIC NAMES		Parks 1	Finger 2	Perry 3	Garbe 4	Goudreau 5	Herman 6	Crouche 7	Obatanga 8
TREES									
Balsam fir	Abies balsamea	-	-	*	*	*	*	*	*
White Spruce	Picea glauca	-	0	0	*	*	0	0	0
Black Spruce	Picea mariana	-	-	*	-	0	-	0	0
Trembling Aspen	Populus tremuloides	*	0	*	-	*	0	*	*
White Birch	Betula papyrifera	*	*	*	*	*	*	*	*
White Cedar	Thuja occidentalis	-	*	0	-	-	0	-	0
Jack Pine	Pinus banksiana	-	-	-	-	0	-	-	-
Balsam Poplar	Populus balsamifera	-	-	-	-	0	-	0	-
Larch	Larix laricina	-	-	-	-	0	-	-	-
Cottonwood	Populus deltoides	-	-	-	-	-	0	-	-
Red Maple	Acer rubrum	-	-	-	-	-	-	*	-
Yew	Taxus canadensis	0	*	-	-	-	-	-	-
SHRUBS									
Mountain Maple	Acer spicatum	*	*	*	-	0	*	*	*
Showy Mountain Ash	Sorbus decora	*	*	*	*	0	*	*	*
Round-leaved Service Berry	Amelanchier sanguinea	0	-	0	0	*	*		0
Speckled Alder	Alnus rugosa	0	*	*	0	0	0		0
Bush Honey Suckle	Diervilla lonicera	*	-	-	*	*	*	*	0
Low Sweet Blueberry	Vaccinium angustifolium	*	*	*	0	*	*	*	0
Velvet-leaved Blueberry	Vaccinium myrtilloides	-	*	*	0	*	*	*	*

Table 21 (Continued)

COMMON AND SCIENTIFIC NAMES		Parks 1	Finger 2	Perry 3	Garbe 4	Goudreau 5	Herman 6	Crouche 7	Obatanga 8
Labrador Tea	Ledum groenlandicum	-	-	0	0	-	-	-	0
Leather Leaf	Chamaedaphne calyculata	0	0	-	-	-	-	-	0
Bog Rosemary	Andromeda glaucophylla	-	-	-	-	-	0	-	0
Red Raspberry	Rubus idaeus	-	*	*	0	*	0	-	0
Downy Raspberry	Rubus pubescens	-	-	0	0	0	-	0	0
Pin Cherry	Prunus pensylvanica	0	*	0	*	*	0	0	-
Prairie Willow	Salix humilis	*	*	-	-	*	0	-	-
Elderberry	Sambucus pubens	0	0	0	-	-	0	-	-
Red Ozier Dogwood	Cornus stolonifera	*	-	0	-	0	0	-	-
Bristly Rose	Rosa acicularis	-	-	-	*	*	-	-	-
Mooseberry	Viburnum edule	-	-	-	-	0	-	-	-
Fly Honeysuckle	Lonicera canadensis	-	-	-	-	0	-	-	-
Skunk Currant	Ribes glandulosum	-	-	-	-	0	*	-	-
Beaked Hazel	Corylus cornuta	-	-	-	-	-	-	*	-
Cranberry	Vaccinium oxycoccos	-	-	-	-	-	-	-	0
HERBACEOUS PLANTS									
Creeping Snowberry	Gaultheria hispidula	0	0	-	-	-	-	0	0
Twinflower	Linnaea borealis	0	*	*	0	*	-	0	*
Partridge Berry	Mitchella repens	-	-	-	-	-	-	-	0
Bunchberry	Cornus canadensis	*	*	*	*	*	*	*	*
Starflower	Trientalis borealis	-	-	*	*	0	-	*	*
Large-leaved Aster	Aster macrophyllum	*	*	*	*	*	*	*	*
Mayflower	Maianthemum canadense	*	*	*	*	*	*	*	*
Goldthread	Coptis groenlandica	-	*	*	*	-	-	*	*

Table 21 (Continued)

COMMON AND SCIENTIFIC NAMES		Parks 1	Finger 2	Perry 3	Garbe 4	Goudreau 5	Herman 6	Crouche 7	Obatanga 8
Violet	Viola sp.	*	0	*	*	*	0	*	0
Wild Sarsaparilla	Aralia nudicaulis	*	0	*	*	*	*	*	0
Corn Lily	Clintonia borealis	-	*	*	*	*	*	*	*
Rosy Twisted Stalk	Streptopus roseus	-	-	-	-	0	-	*	0
Joe Pye Weed	Eupatorium maculatum	-	-	-	-	-	0	-	0
Pearly Everlasting	Anaphalis margaritacea	*	-	0	0	0	0	0	0
Sweet Coltsfoot	Petasites palmatus	-	0	-	0	0	-	-	0
Fireweed	Epilobium angustifolium	*	0	0	0	*	*	-	0
Shinleaf	Pyrola rotundifolia	*	-	-	-	0	0	-	0
Indian Pipes	Monotropa uniflora	-	-	0	0	0	-	0	0
Blue Flag	Iris versicolor	0	-	-	0	-	0	-	0
Blue Aster	Aster ciliolatus	0	0	-	0	-	0	-	-
Sheep Sorrel	Rumex acetosella	*	-	-	-	-	-	-	-
Orange Hawkweed	Hieracium auranticum	*	-	-	-	-	-	-	-
Yellow Hawkweed	Hieracium canadense	0	-	0	-	0	0	-	-
Yarrow	Achillea millefolium	*	-	-	-	0	*	-	-
Daisy	Chyrysanthemum leucanthemum	*	-	-	-	-	0	-	-
Bindweed	Polygonum cilinode	0	0	0	-	-	0	0	-
Giant Goldenrod	Solidago squarrosa	0	0	0	0	-	-	-	-
Red Clover	Trifolium pratense	*	-	-	-	-	0	-	-
Self Heal	Prunella vulgaris	*	-	-	-	-	0	-	-
Evening Primrose	Oenothera biennis	0	-	-	-	-	-	-	-
Wormwood	Artemisia vulgaris	0	-	-	-	-	-	-	-

Table 21 (Continued)

COMMON AND SCIENTIFIC NAMES		Parks 1	Finger 2	Perry 3	Garbe 4	Goudreau 5	Herman 6	Crouche 7	Obatanga 8
Trailing Arbutus	Epigaea repens	-	-	0	-	0	-	-	-
Cow Wheat	Melampyrum lineare	-	-	0	0	0	-	-	-
Dwarf Mistletoe	Arceuthobium pusillum	-	-	0	-	-	-	-	-
Pink Lady-Slipper	Cypripedium acaule	-	-	0	0	-	-	-	-
Dwarf Iris	Iris lacustris	-	-	-	0	-	-	-	-
Purple Clematis	Clematis verticillaris	-	-	-	-	0	-	-	-
Bedstraw	Galium triflorum	-	-	-	-	0	0	-	-
Goldenrod	Solidage rugosa	-	-	-	-	0	0	-	-
Wild Strawberry	Fragaria vesca	-	-	-	-	0	-	-	-
Chickweed	Stellaria media	-	-	-	-	0	-	-	-
Mitrewort	Mitella nuda	-	-	-	-	0	-	-	-
Swamp Cinquefoil	Potentilla palustris	-	-	-	-	0	-	-	-
Yellow Avens	Geum macrophyllum	-	-	-	-	0	-	-	-
Red Baneberry	Actea rubra	-	-	-	-	0	-	-	-
Michigan Lily	Lilium michiganense	-	-	-	-	0	-	-	-
Spurred Gentron	Halenia deflexa	-	-	-	-	0	-	-	-
Wild Lettuce	Lactuca biennis	-	-	-	-	-	0	-	-
Dandelion	Taraxacum officinale	-	-	-	-	-	0	-	-
Bugleweed	Lycopus americanus	-	-	-	-	-	0	-	-
Forget-me-not	Myosotis scorpioides	-	-	-	-	-	0	-	-
Loosestrife	Lysimachia thyrsiflora	-	-	-	-	-	0	-	-
Jewelweed	Impatiens capensis	-	-	-	-	-	0	-	-
Bull Thistle	Cirsium vulgare	-	-	-	-	-	*	-	-
Wormseed Mustard	Erysimum cheiranthoides	-	-	-	-	-	0	-	-
Cinquefoil	Potentilla canadensis	-	-	-	-	-	0	-	-

Table 21 (Continued)

COMMON AND SCIENTIFIC NAMES		Parks 1	Finger 2	Perry 3	Garbe 4	Goudreau 5	Herman 6	Crouche 7	Obatanga 8
Purple Meadowrue	Thalictrum dasycarpum	-	-	-	-	-	0	-	-
Skullcap	Scutellaria epilobiifolia	-	-	-	-	-	0	-	-
Corydalis	Corydalis sempervirens	-	-	-	-	-	0	-	-
Herb-Robert	Geranium Robertianum	-	-	-	-	-	0	-	-
Yellow Dock	Rumex crispus	-	-	-	-	-	0	-	-
Plantain	Plantago Rugelli	-	-	-	-	-	0	-	-
Cow Vetch	Vicia cracca	-	-	-	-	-	0	-	-
Pearl Wort	Sagina sp.	-	-	-	-	-	0	-	-
Rattlesnake Plantain	Goodyera sp.	-	-	-	-	-	-	-	*
GRASSES									
Hairgrass	Dechampsia flexuosa	*	*	*	*	*	*	-	0
Blue Joint Grass	Calamagrostis canadensis	0	0	0	-	-	0	-	0
Woody Reed Grass	Cinna latifolia	0	-	*	0	0	-	-	0
Bent Grass	Agrostis alba	0	0	-	-	0	0	-	-
Panic Grass	Panicum languinosum	0	-	-	-	-	-	-	-
Poverty Grass	Danthonia spicata	0	-	-	0	-	-	-	-
Mountain Rice	Oryzopsis asperifolia	-	-	-	-	0	-	-	-
False Melic	Schizachne purpurascens	-	-	-	-	0	-	-	-
Red Fescue	Festuca rubra	-	-	-	-	-	0	-	-
Canada Blue Grass	Poa compressa	-	-	-	-	-	0	-	-
Timothy	Phleum pratense	-	-	-	-	-	0	-	-
Sedges	Carex sp.	*	0	*	0	*	-	0	*

Table 21 (Continued)

COMMON AND SCIENTIFIC NAMES		Parks 1	Finger 2	Perry 3	Garbe 4	Goudreau 5	Herman 6	Crouche 7	Obatanga 8
FERNS									
Interrupted Fern	Osmunda Claytoniana	-	-	*	-	-	-	-	0
Bracken Fern	Pteridium aquilinum	0	0	*	*	*	0	0	*
Spiny Wood Fern	Dryopteris spinulosa	*	*	0	0	0	-	0	*
Oak Fern	Dryopteris disjuncta	-	-	0	0	-	-	-	0
Longbeech Fern	Dryopteris Phegopteris	-	-	-	-	-	-	-	0
Lady Fern	Athyrium filix-femina	-	-	-	-	0	-	-	0
Grape Fern	Botrychium multifidum	0	-	-	-	-	-	-	-
Polypody	Polypodium virginianum	-	-	0	-	0	-	-	-
Rattlesnake Fern	Botrychium virginianum	-	-	0	-	0	-	-	-
Rusty Woodsia Fern	Woodsia ilvensis	-	-	-	0	0	-	-	-
CLUB MOSSES									
Shining Club Moss	Lycopodium lucidulum	-	-	0	0	*	*	*	*
Ground Pine	Lycopodium tristachyum	*	-	0	*	-	0	0	-
Bristly Club Moss	Lycopodium annotinum	-	-	-	*	-	0	-	-
Ground Cedar	Lycopodium complanatum	-	-	-	0	0	0	*	-
Staghorn Club Moss	Lycopodium clavatum	-	-	-	-	0	0	-	-
HORSETAILS									
Wood Horsetail	Equisetum sylvaticum	-	-	0	-	0	-	-	0
Meadow Horsetail	Equisetum pratense	-	-	*	-	-	0	-	-
Water Horsetail	Equisetum fluviatile	-	-	-	-	-	0	-	-

Table 22

SPECIES DIVERSITY INDEX VALUES COMPUTED FOR PERMANENT GRIDS ESTABLISHED IN THE WAWA AREA - 1969 - 1973

PLOT	1969	1970	1971	1972	1973
Parks Lake	2.95	3.00	2.90	2.98	3.00
Finger Lake	2.72	2.54	2.56	2.57	2.77
Perry Lake	2.53	2.71	2.94	2.92	3.11
Garbe Lake	2.24	1.95	2.10	1.94	2.04
Goudreau	3.04	2.76	3.04	3.20	2.99
Herman Lake	2.59	2.59	2.79	2.73	2.76
Crouche Lake	2.42	2.45	2.35	2.94	2.73
Obatanga Park	3.24	3.11	3.10	3.02	2.53

SUMMARY OF DATA COLLECTED FROM GROUND FLORA POPULATIONS STUDIES

IN THE WAWA AREA - JULY 1975

Table 23

PLOT	NUMBER OF SPECIES				PERCENT COVER			
	Trees	Shrubs	Herbs	TOTAL	Trees	Shrubs	Herbs	TOTAL
Highway 17	3	10	18	31	57	76	126	259
Lucy Pit	2	7	21	30	12	29	104	145
Parks Lake	2	17	24	37	12	76	161	249
Finger Lake	1	7	12	20	26	119	59	204
Perry Lake	5	8	19	32	76	70	94	240
Garbe Lake	4	10	15	29	68	66	141	275
Goudreau	7	12	20	39	72	48	133	253
Troupe Lake	5	9	16	30	86	73	82	241
Dubreuil Road	4	7	21	32	35	101	85	221
Obatanga Park	4	6	17	27	102	35	47	184

Table 24

CONCENTRATIONS OF SULPHUR (%) IN TREMBLING ASPEN FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1969 - 1973 **

PLOT	YEAR				
	1969	1970	1971	1972	1973
Parks Lake	-	.29	.57	.61	.44
Finger Lake	-	-	-	-	-
Perry Lake	.27	.25	.34	.47	.34
Garbe Lake	-	-	-	-	-
Goudreau	.34	.25	.35	.45	.31
Herman Lake	-	.22	.34	.37	.27
Crouche Lake *	.23	.21	.23	.31	.23
Obatanga Park *	.30	.17	.36	.30	.25

* Control locations

** Values reported are means of one monthly sample in 1969, four monthly samples in 1970 and three monthly samples in 1971 through 1973.

Table 25

CONCENTRATIONS OF SULPHUR (%) IN WHITE BIRCH FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1969 - 1976**

PLOT	YEAR							
	1969	1970	1971	1972	1973	1974	1975	1976
Highway 17	--	--	--	--	--	--	.38	.19
Lucy Pit	--	--	--	--	--	.48	.54	.39
Parks Lake	.26	.25	.49	.41	.44	.58	.44	.39
Finger Lake	.35	.24	.34	.43	.32	.46	.37	.32
Perry Lake	.28	.28	.28	.33	.27	.30	.26	.25
Garbe Lake	.30	.24	.32	.33	.31	.30	.25	.19
Goudreau	.23	.18	.31	.26	.27	.27	.23	.17
Herman Lake	.31	.19	.26	.28	.22	--	--	--
Troupe Lake	--	--	--	--	--	.29	.09	.13
Crouche Lake*	.19	.16	.17	.23	.18	--	--	--
Dubreuil Rd.*	--	--	--	--	--	.14	.11	.09
Obatanga Pk.*	.25	.15	.19	.24	.16	.17	.09	.10

* Control locations

** Values reported are means of one monthly sample in 1969, four monthly samples in 1970, three monthly samples in 1971 through 1974 and two monthly samples in triplicate in 1975 and 1976.

Table 26

CONCENTRATIONS OF SULPHUR (%) IN MOUNTAIN MAPLE FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1969 - 1974**

	YEAR					
PLOT	1969	1970	1971	1972	1973	1974
Parks Lake	.32	.24	.35	.60	.48	.44
Finger Lake	.29	.39	.38	.52	.41	.39
Perry Lake	.25	.17	.28	.37	.30	.30
Garbe Lake	--	--	--	--	--	--
Goudreau	.26	.24	.29	.45	.29	.30
Herman Lake	.24	.16	.22	.27	.29	--
Crouche Lake*	.22	.19	.26	.27	.21	--
Obatanga Park*	--	.20	.22	.19	.23	.20

* Control locations

** Values reported are means of one monthly sample in 1969, four monthly samples in 1970 and three monthly samples in 1971 through 1974.

Table 27

CONCENTRATIONS OF SULPHUR (%) IN SHOWY MOUNTAIN ASH FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1969 - 1973**

	YEAR				
PLOT	1969	1970	1971	1972	1973
Parks Lake	--	.21	.27	.51	.47
Finger Lake	.41	.23	.37	.52	.36
Perry Lake	.29	.20	.27	.40	.23
Garbe Lake	--	.18	.29	.30	.24
Goudreau	--	.16	--	--	--
Herman Lake	.20	.14	.22	.21	.14
Crouche Lake*	--	.13	.20	.16	.16
Obatanga Park*	--	.14	.17	.16	.15

* Control location

** Values reported are means of one monthly sample in 1969, four monthly samples in 1970, and three monthly samples in 1971 through 1973.

Table 28

CONCENTRATIONS OF SULPHUR (%) IN GRASS
FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA
1970 - 1974**

	YEAR				
PLOT	1970	1971	1972	1973	1974
Parks Lake	.18	.39	.44	.31	.43
Finger Lake	.16	.43	.28	.34	.30
Perry Lake	.21	.16	.24	.16	.26
Garbe Lake	.15	.27	.25	.20	.21
Goudreau	.17	.24	.24	.17	.21
Herman Lake	.16	.21	.20	.15	--
Crouche Lake*	.16	.17	.22	.15	--
Obatanga Park*	.21	.30	.20	.14	.27

* Control location

** Values reported are means of four monthly samples in 1970 and three monthly samples in 1971 through 1974.

Table 29

CONCENTRATIONS OF ARSENIC (µg/g) IN TREMBLING ASPEN FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1970 - 1973**

	YEAR			
PLOT	1970	1971	1972	1973
Parks Lake	22.8	9.1	8.1	6.8
Finger Lake	---	---	---	---
Perry Lake	5.8	2.2	2.5	2.7
Garbe Lake	---	---	---	---
Goudreau	3.3	2.5	2.0	2.1
Herman Lake	5.8	2.3	1.8	2.1
Crouche Lake*	1.9	1.5	1.1	0.5
Obatanga Park*	0.7	0.9	0.8	0.3

* Control locations

** Values reported are means of four monthly samples in 1970 and three monthly samples in 1971 through 1973.

Table 30

CONCENTRATIONS OF ARSENIC (µg/g) IN WHITE BIRCH FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1970 - 1976**

PLOT	YEAR 1970	1971	1972	1973	1974	1975	1976
Highway 17	---	---	---	---	---	21.2	3.7
Lucy Pit	---	---	---	---	28.1	18.7	7.2
Parks Lake	19.6	9.0	5.4	9.3	17.0	10.6	5.2
Finger Lake	14.1	6.2	5.7	8.6	8.6	7.9	3.1
Perry Lake	8.0	3.1	3.5	4.2	3.7	5.7	1.8
Garbe Lake	9.9	3.8	2.8	8.4	2.2	4.6	1.5
Goudreau	7.5	3.0	1.3	4.0	2.8	4.4	1.1
Herman Lake	6.6	2.9	2.2	2.7	---	---	---
Troupe Lake	---	---	---	---	4.1	2.6	1.3
Crouche Lake*	2.6	1.2	1.2	0.7	---	---	---
Dubreuil Rd*	---	---	---	---	0.8	1.4	0.4
Obatanga Pk*	0.8	1.0	0.6	0.4	0.9	0.4	0.3

* Control locations

** Values reported are means of four monthly samples in 1970, three monthly samples in 1971 through 1974 and two monthly samples in triplicate in 1975 and 1976.

CONCENTRATIONS OF ARSENIC (µg/g) IN MOUNTAIN MAPLE FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1970 - 1974**

	YEAR				
PLOT	1970	1971	1972	1973	1974
Parks Lake	18.2	5.9	5.3	6.9	6.1
Finger Lake	7.8	4.6	4.2	5.8	4.9
Perry Lake	5.3	3.3	3.0	2.5	2.5
Garbe Lake	---	---	---	---	---
Goudreau	3.7	2.0	2.0	1.7	1.5
Herman Lake	3.7	1.6	1.9	2.0	---
Crouche Lake*	1.9	1.1	1.0	0.3	---
Obatanga Park*	0.6	0.7	0.9	0.3	0.3

* Control locations

** Values reported are means of four monthly samples in 1970 and three monthly samples in 1971 through 1974.

Table 32

CONCENTRATIONS OF ARSENIC (µg/g) IN SHOWY MOUNTAIN ASH FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1970 - 1973**

	YEAR			
PLOT	1970	1971	1972	1973
Parks Lake	15.0	6.7	5.3	12.6
Finger Lake	11.3	4.6	2.7	4.4
Perry Lake	6.6	2.9	2.3	3.5
Garbe Lake	9.4	2.5	1.6	3.3
Goudreau	3.5	---	---	---
Herman Lake	4.5	2.5	1.7	2.1
Crouche Lake*	1.4	1.4	1.0	0.5
Obatanga Park*	0.7	0.7	0.9	< 0.3

* Control locations

** Values reported are means of four monthly samples in 1970 and three monthly samples in 1971 through 1973.

Table 33

CONCENTRATIONS OF ARSENIC (µg/g) IN GRASS FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1970 - 1974**

PLOT	YEAR 1970	1971	1972	1973	1974
Parks Lake	8.4	4.4	5.4	4.3	4.9
Finger Lake	4.8	3.3	4.2	2.9	3.3
Perry Lake	5.6	2.4	4.0	3.2	3.0
Garbe Lake	5.1	3.9	2.0	2.7	1.1
Goudreau	2.2	1.7	1.9	0.8	1.1
Herman Lake	3.0	2.3	1.5	1.4	---
Crouche Lake*	0.9	1.1	1.2	0.3	---
Obatanga Park*	0.5	1.0	1.1	0.3	0.3

* Control locations

** Values reported are means of four monthly samples in 1970 and three monthly samples in 1971 through 1974.

Table 34

CONCENTRATIONS OF IRON (ug/g) IN TREMBLING ASPEN FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1970 - 1973**

PLOT	YEAR 1970	1971	1972	1973
Parks Lake	73	124	256	231
Finger Lake	--	--	--	--
Perry Lake	56	71	62	121
Garbe Lake	--	--	--	--
Goudreau	--	71	55	78
Herman Lake	53	90	68	75
Crouche Lake*	60	72	63	74
Obatanga Park*	51	87	65	69

* Control locations

** Values reported are means of four monthly samples in 1970 and three monthly samples in 1971 through 1973.

Table 35

CONCENTRATIONS OF IRON (ug/g) IN WHITE BIRCH FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1970 - 1976**

PLOT	YEAR						
	1970	1971	1972	1973	1974	1975	1976
Highway 17	--	--	--	--	--	1253	798
Lucy Pit	--	--	--	--	813	917	773
Parks Lake	51	325	184	407	1133	408	390
Finger Lake	65	155	129	178	679	305	197
Perry Lake	38	115	92	174	269	260	149
Garbe Lake	64	120	96	150	287	263	116
Goudreau	55	96	78	111	157	244	118
Herman Lake	64	104	94	88	--	--	--
Troupe Lake	--	--	--	--	450	267	171
Crouche Lake *	44	81	68	60	--	--	--
Dubreuil Road*	--	--	--	--	187	158	163
Obatanga Park*	47	77	73	78	111	66	65

* Control locations

** Values reported are means of four monthly samples in 1970, three monthly samples in 1971 through 1974 and two monthly samples in triplicate in 1975 and 1976.

Table 36

CONCENTRATIONS OF IRON (ug/g) IN MOUNTAIN MAPLE FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1970 - 1974**

PLOT	YEAR 1970	1971	1972	1973	1974
Parks Lake	85	229	245	442	810
Finger Lake	59	128	147	273	316
Perry Lake	52	133	108	130	418
Garbe Lake	--	--	--	--	188
Goudreau	46	117	128	144	156
Herman Lake	46	86	91	127	--
Crouche Lake*	58	81	76	78	--
Obatanga Park*	69	93	71	78	87

* Control locations

** Values reported are means of four monthly samples in 1970 and three monthly samples in 1971 through 1974.

Table 37

CONCENTRATIONS OF IRON (ug/g) IN SHOWY MOUNTAIN ASH FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1970 - 1973**

PLOT	YEAR 1970	1971	1972	1973
Parks Lake	63	250	164	298
Finger Lake	39	137	113	208
Perry Lake	31	117	82	160
Garbe Lake	31	96	91	115
Goudreau	--	--	--	--
Herman Lake	40	124	79	108
Crouche Lake*	37	88	86	82
Obatanga Park*	43	90	67	66

* Control locations

** Values reported are means of four monthly samples in 1970 and three monthly samples in 1971 through 1973.

Table 38

CONCENTRATIONS OF IRON (ug/g) IN GRASS
FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA
1970 - 1974**

PLOT	YEAR 1970	1971	1972	1973	1974
Parks Lake	62	120	101	156	231
Finger Lake	49	122	63	78	113
Perry Lake	40	50	67	81	145
Garbe Lake	40	69	54	63	95
Goudreau	48	87	58	53	91
Herman Lake	46	71	49	63	--
Crouche Lake*	72	74	49	57	--
Obatanga Park*	53	63	49	54	58

* Control locations

** Values reported are means of four monthly samples in 1970 and three monthly samples in 1971 through 1974.

Table 39

CONCENTRATIONS OF ZINC (ug/g) IN TREMBLING ASPEN FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1970 - 1973**

PLOT	YEAR 1970	1971	1972	1973
Parks Lake	380	377	391	158
Finger Lake	---	---	---	---
Perry Lake	300	250	267	152
Garbe Lake	---	---	---	---
Goudreau	264	225	203	183
Herman Lake	307	235	178	170
Crouche Lake*	190	168	179	208
Obatanga Park*	151	178	150	139

* Control locations

** Values reported are means of four monthly samples in 1970 and three monthly samples in 1971 through 1973.

Table 40

CONCENTRATIONS OF ZINC (ug/g) IN WHITE BIRCH FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1970 - 1974**

PLOT	YEAR 1970	1971	1972	1973	1974
Highway 17	---	---	---	---	---
Lucy Pit	---	---	---	---	389
Parks Lake	226	330	322	184	319
Finger Lake	240	253	225	166	376
Perry Lake	252	270	256	80	194
Garbe Lake	188	197	154	111	195
Goudreau	198	290	255	129	151
Herman Lake	152	173	140	130	---
Troupe Lake	---	---	---	---	270
Crouche Lake*	228	188	112	131	---
Dubreuil Road *	---	---	---	---	150
Obatanga Park *	88	217	129	108	118

* Control locations

** Values reported are means of four monthly samples in 1970 and three monthly samples in 1971 through 1974.

Table 41

CONCENTRATIONS OF ZINC (ug/g) IN MOUNTAIN MAPLE FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1970 - 1974**

PLOT	YEAR 1970	1971	1972	1973	1974
Parks Lake	37	44	74	40	42
Finger Lake	43	41	53	41	44
Perry Lake	40	35	32	31	42
Garbe Lake	--	--	--	--	--
Goudreau	27	33	37	45	42
Herman Lake	37	36	54	31	--
Crouche Lake*	45	33	52	38	--
Obatanga Park*	33	34	41	34	56

* Control locations

** Values reported are means of four monthly samples in 1970 and three monthly samples in 1971 through 1974.

Table 42

CONCENTRATIONS OF ZINC (ug/g) IN SHOWY MOUNTAIN ASH FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA 1970 - 1973**

PLOT	YEAR 1970	1971	1972	1973
Parks Lake	28	30	25	12
Finger Lake	25	21	23	17
Perry Lake	28	18	19	18
Garbe Lake	24	23	16	15
Goudreau	18	--	--	--
Herman Lake	24	17	22	19
Crouche Lake*	27	25	39	67
Obatanga Park*	31	24	60	32

* Control locations

** Values reported are means of four monthly samples in 1970 and three monthly samples in 1971 through 1973.

Table 43

CONCENTRATIONS OF ZINC (ug/g) IN GRASS
FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA
1970 - 1974**

	YEAR				
PLOT	1970	1971	1972	1973	1974
Parks Lake	37	34	59	27	32
Finger Lake	40	36	73	27	34
Perry Lake	37	33	31	22	39
Garbe Lake	50	26	43	22	35
Goudreau	37	31	23	29	29
Herman Lake	39	47	77	22	--
Crouche Lake*	35	30	53	19	--
Obatanga Park*	50	41	51	20	31

* Control locations

** Values reported are means of four monthly samples in 1970 and three monthly samples in 1971 through 1974.

Table 44

CONCENTRATIONS OF MANGANESE (ug/g) IN SOIL & WHITE BIRCH FOLIAGE SAMPLES COLLECTED IN THE WAWA AREA - 1976*

PLOT	WHITE BIRCH	SOIL
Highway 17	1800	2933
Lucy Pit	2433	190
Parks Lake	1207	373
Finger Lake	2867	217
Perry Lake	3166	40
Garbe Lake	1733	283
Goudreau	850	390
Troupe Lake	787	44
Dubreuil Road *	1400	74
Obatanga Park *	1833	7

* Control locations

** Values reported are means of one monthly sample (August) in triplicate.

Table 45

CONCENTRATIONS OF FLUORIDE (ug/g) IN SOIL AND VEGETATION SAMPLES COLLECTED IN THE WAWA AREA - 1970*

PLOT	WHITE BIRCH	TREMBLING ASPEN	MOUNTAIN MAPLE	MOUNTAIN ASH	FORAGE	SOIL
Parks Lake	5	2	13	5	2	120
Finger Lake	6	-	17	8	3	80
Perry Lake	3	7	5	4	3	160
Garbe Lake	13	-	-	11	7	100
Goudreau	4	4	3	5	3	100
Herman Lake	7	4	8	7	3	120
Crouche Lake *	4	8	4	5	4	100
Obatanga Park*	6	4	4	8	3	60

* Control locations

** Values reported are means of three monthly samples (June, August, September).

Table 46

CONCENTRATIONS OF LEAD (ug/g) IN VEGETATION

COLLECTED IN THE WAWA AREA - 1973-1974

PLOT	SAMPLE							
	WHITE BIRCH		TREMBLING ASPEN	MOUNTAIN MAPLE		SHOWY MOUNTAIN ASH	GRASS FORAGE	
	1973	1974	1973	1973	1974	1973	1973	1974
Lucy Pit	--	9	--	--	7	--	--	2
Parks Lake	9	12	12	9	12	20	12	6
Finger Lake	13	17	--	9	11	9	8	6
Perry Lake	10	13	5	4	13	10	10	6
Garbe Lake	7	13	--	--	13	7	7	6
Goudreau	8	7	12	15	8	--	12	3
Herman Lake	9	--	8	8	--	8	15	--
Troupe Lake	--	17	--	--	14	--	--	8
Crouche Lake*	13	--	13	15	--	16	15	--
Dubreuil Road*	--	5	--	--	--	--	--	4
Obatanga Park*	18	6	14	10	8	10	10	3

* Control locations

** Values reported are means of two monthly samples (July, August) in 1973 and one monthly sample (August) in 1974.

Table 47

CONCENTRATIONS OF CADMIUM (ug/g) IN VEGETATION AND SOIL SAMPLES COLLECTED IN THE WAWA AREA - 1973**

PLOT	SAMPLE					
	WHITE BIRCH	TREMBLING ASPEN	MOUNTAIN MAPLE	SHOWY MOUNTAIN ASH	GRASS FORAGE	SOIL
Parks Lake	1.0	1.2	0.9	0.6	0.4	0.3
Finger Lake	1.9	---	0.9	0.7	0.6	0.8
Perry Lake	1.1	0.9	0.6	0.8	0.5	0.5
Garbe Lake	0.9	---	---	0.9	0.8	1.0
Goudreau	1.0	1.0	1.0	---	1.0	1.0
Herman Lake	0.7	0.7	0.7	0.8	0.6	1.0
Crouche Lake *	1.0	1.0	1.0	1.0	1.0	0.8
Obatanga Park*	1.0	1.0	1.0	1.0	1.0	---

* Control locations

** Values reported are for two monthly samples (July, August).

Table 48

CONCENTRATIONS OF CHROMIUM (ug/g) IN VEGETATION AND SOIL SAMPLES COLLECTED IN THE WAWA AREA - 1973**

PLOT	SAMPLE					
	WHITE BIRCH	TREMBLING ASPEN	MOUNTAIN MAPLE	SHOWY MOUNTAIN ASH	GRASS FORAGE	SOIL
Parks Lake	< 1	< 1	< 1	< 1	2	15
Finger Lake	< 1	--	< 1	< 1	4	11
Perry Lake	< 1	< 1	< 1	2	2	6
Garbe Lake	--	--	--	1	3	10
Goudreau	1	1	1	--	1	6
Herman Lake	1	1	1	1	1	13
Crouche Lake *	1	1	4	3	1	8
Obatanga Park*	1	1	3	5	1	--

* Control locations

** Values reported are for one monthly sample (August).

Table 49

Concentrations of Sulphur (%) in Soil Samples

Collected in the Wawa Area - 1970-1976**

PLOT	YEAR						
	1970	1971	1972	1973	1974	1975	1976
Highway 17	-	-	-	-	-	.08	.06
Lucy Pit	-	-	-	-	.04	.08	.05
Parks Lake	.05	.03	.03	.04	.05	.05	.05
Finger Lake	.05	.06	.03	.06	.04	.09	.05
Perry Lake	.03	.02	.03	.04	.04	.12	.08
Garbe Lake	.03	.02	.02	.04	.03	.06	.07
Goudreau	.03	.02	.03	.07	.03	.04	.05
Herman Lake	.02	.02	.03	.02	-	-	-
Troupe Lake	-	-	-	-	.03	.04	.02
Crouche Lake *	.02	.02	.02	.03	-	-	-
Dubreuil Road *	-	-	-	-	.02	.04	.01
Obatanga Park *	.01	.01	.02	.02	.02	.02	.01

* Control locations

** Reported values are based on two monthly samples from 1970 through 1974 and two monthly samples in triplicate in 1975 and 1976.

Table 50

Concentrations of Iron (%) in Soil Samples
Collected in the Wawa Area - 1970-1976**

PLOT	YEAR 1970	1971	1972	1973	1974	1975	1976
Highway 17	-	-	-	-	-	2.46	4.18
Lucy Pit	-	-	-	-	2.49	1.21	5.24
Parks Lake	1.92	2.83	1.24	1.06	1.91	1.97	1.65
Finger Lake	1.92	3.52	2.06	0.94	1.94	0.86	1.64
Perry Lake	0.67	0.37	0.65	2.20	0.45	1.41	0.30
Garbe Lake	2.20	1.83	1.65	1.92	1.36	1.12	2.17
Goudreau	1.96	2.39	1.35	1.20	1.73	1.48	1.85
Herman Lake	1.36	1.27	1.49	0.59	-	-	-
Troupe Lake	-	-	-	-	1.33	0.51	1.17
Crouche Lake *	0.85	0.75	0.67	0.56	-	-	-
Dubreuil Road *	-	-	-	-	0.62	0.38	0.40
Obatanga Park *	0.08	0.10	0.32	-	0.46	0.04	0.02

* Control locations
** Reported values are based on two monthly samples from 1970 through 1974 and two monthly samples in triplicate in 1975 and 1976.

Table 51

Concentrations of Arsenic (ug/g) in Soil Samples

Collected in the Wawa Area - 1970-1976**

PLOT	YEAR						
	1970	1971	1972	1973	1974	1975	1976
Highway 17	-	-	-	-	-	92.0	233.0
Lucy Pit	-	-	-	-	28.1	52.3	10.1
Parks Lake	56.7	56.5	48.4	53.0	63.8	43.6	29.9
Finger Lake	24.4	24.9	20.5	13.0	13.8	8.7	10.2
Perry Lake	9.6	6.5	6.9	2.1	8.5	13.1	2.8
Garbe Lake	19.6	-	16.2	21.0	21.0	6.6	14.7
Goudreau	6.4	8.4	8.2	20.0	6.4	4.1	5.0
Herman Lake	4.1	6.9	11.0	4.0	-	-	-
Troupe Lake	-	-	-	-	17.2	5.1	5.4
Crouche Lake *	2.1	4.9	3.2	1.9	-	-	-
Dubreuil Road *	-	-	-	-	1.7	0.9	0.8
Obatanga Park *	0.7	2.0	4.1	0.4	0.8	0.1	0.3

* Control locations

** Reported values are based on two monthly samples from 1970 through 1974 and two monthly samples in triplicate in 1975 and 1976.

Table 52

Concentrations of Zinc (ug/g) in Soil Samples

Collected in the Wawa Area 1970-1974 **

	YEAR				
PLOT	1970	1971	1972	1973	1974
Highway 17	-	-	-	-	-
Lucy Pit	-	-	-	-	49
Parks Lake	57	68	48	29	42
Finger Lake	23	63	82	32	50
Perry Lake	18	17	43	5	24
Garbe Lake	36	37	64	10	38
Goudreau	55	89	89	63	53
Herman Lake	21	24	70	19	-
Troupe Lake	-	-	-	-	35
Crouche Lake *	24	27	79	15	-
Dubreuil Road *	-	-	-	-	28
Obatanga Park *	3	9	54	-	14

* Control locations
** Reported values are based on two monthly samples in each year.

Table 53

Concentrations of Calcium (ug/g) in Soil Samples Collected in the Wawa Area - 1973-1976 **

PLOT	YEAR 1973	1974	1975	1976
Highway 17	-	-	622	417
Lucy Pit	-	1400	521	56
Parks Lake	37	383	536	315
Finger Lake	117	725	1832	1043
Perry Lake	63	253	504	247
Garbe Lake	60	451	991	1683
Goudreau	150	1500	761	2427
Herman Lake	117	-	-	-
Troupe Lake	-	1128	742	716
Crouche Lake *	33	-	-	-
Dubreuil Road*	-	325	910	174
Obatanga Park*	-	600	529	95

* Control locations
** Reported values are based on two monthly samples in 1973 and 1974 and two monthly samples in triplicate in 1975 and 1976.

Table 54

Concentrations of Magnesium (ug/g) in Soil Samples Collected in the Wawa Area - 1973-1976 **

PLOT	YEAR 1973	1974	1975	1976
Highway 17	-	-	3285	4367
Lucy Pit	-	1600	2101	977
Parks Lake	1235	2015	3025	1683
Finger Lake	1135	963	1277	1593
Perry Lake	515	445	808	291
Garbe Lake	869	1565	3170	8667
Goudreau	1090	1550	1892	7100
Herman Lake	769	-	-	-
Troupe Lake	-	619	656	625
Crouche Lake *	532	-	-	-
Dubreuil Road*	-	55	1404	708
Obatanga Park*	-	613	123	60

* Control locations
** Reported values are based on two monthly samples in 1973 and 1974 and two monthly samples in triplicate in 1975 and 1976.

Table 55

pH Values of Soil Samples

Collected in the Wawa Area - 1969-1975 **

PLOT	July 1969	June 1970	Sept. 1970	June 1971	August 1971	June 1972	August 1972	June 1973	August 1973	July 1975	Range
Highway 17	-	-	-	-	-	-	-	-	-	4.7	4.7
Lucy Pit	-	-	-	-	-	-	-	-	-	4.3	4.3
Parks Lake	4.5	5.0	5.0	4.6	4.8	4.6	4.2	-	4.7	4.7	4.2-5.0
Finger Lake	3.4	4.3	3.5	4.3	4.9	4.6	4.6	4.1	4.5	3.8	3.4-4.9
Perry Lake	3.9	4.7	4.0	4.0	4.7	3.8	5.2	4.4	4.9	4.1	3.8-5.2
Garbe Lake	4.6	4.7	4.5	4.5	4.9	4.1	4.3	4.4	4.4	4.7	4.1-4.9
Goudreau	5.0	5.3	5.2	5.1	4.5	5.0	3.2	4.4	4.0	5.1	3.2-5.3
Herman Lake	4.5	5.0	5.3	4.8	4.4	5.5	4.7	4.5	4.7	-	4.4-5.5
Troupe Lake	-	-	-	-	-	-	-	-	-	4.2	4.2
Crouche Lake*	4.2	4.6	4.8	4.5	4.6	4.1	4.6	4.5	4.5	-	4.1-4.8
Dubreuil Road*	-	-	-	-	-	-	-	-	-	5.1	5.1
Obatanga Park*	3.7	4.5	4.3	4.2	4.5	4.0	4.2	3.7	4.6	4.3	3.7-4.6

* Control locations

** Values reported are from single samples in 1969 to 1973 and means of triplicate samples in 1975.

Table 56

Concentrations of Arsenic (ug/g) in Soil Samples

Collected in the Wawa Area Arsenic Study in 1975

Site	Location	Depth of sample (cm) 0-5	5-10	10-15
Site 1	1.1 km N	566.3	478.3	207.0
Site 2	2.2 km NE	487.3	97.5	86.1
Site 3	4.2 km NE	98.8	18.0	20.0
Site 4	6.3 km NE	199.6	83.0	80.9
Site 5	7.7 km NE	160.4	71.8	15.4
Site 6	10.8 km NE	45.3	13.2	3.0
Site 7	13.8 km NE	47.7	9.3	6.1
Parks Lake	16 km NE	60.6	36.3	13.8
Finger Lake	19 km NE	15.9	10.0	9.6
Perry Lake	26 km NE	7.1	2.9	3.3
Garbe Lake	30 km NE	10.6	5.2	6.0
Goudreau	35 km NE	11.0	8.6	6.7
Troupe Lake	40 km NE	6.7	2.9	2.0
Dubreuil Road	45 km NNE	2.8	1.1	0.9
Lucy Pit	12 km ENE	23.8	15.6	12.6
Hawk Junction	21 km E	3.8	2.1	2.0
Highway 17	1.6 km SW	544.0	28.8	8.3
Mission Road	8.0 km SSW	12.3	4.0	3.5
Michipicoten Harbour	9.0 km SW	10.1	3.5	2.6
Obatanga Park	56 km NW	0.4	0.3	0.3
Government Rd. Wawa	0.5 km SE	728.0	75.4	15.2
Wawa Park	1.6 km SE	38.2	8.8	6.7
Beck Public School	2.2 km SE	14.4	2.7	4.1
Centennial Park	1.7 km SSE	35.0	5.1	8.2

Table 57

Concentrations of Sulphur (%) in Soil Samples

Collected in the Wawa Area Arsenic Study in 1975

Site	Location	Depth of sample (cm) 0-5	5-10	10-15
Site 1	1.1 km N	0.10	0.08	0.07
Site 2	2.2 km NE	0.12	0.08	0.09
Site 3	4.2 km NE	0.08	0.09	0.09
Site 4	6.3 km NE	0.10	0.08	0.07
Site 5	7.7 km NE	0.08	0.07	0.08
Site 6	10.8 km NE	0.07	0.07	0.07
Site 7	13.8 km NE	0.07	0.04	0.07
Parks Lake	16 km NE	0.07	0.05	0.07
Finger Lake	19 km NE	0.07	0.07	0.07
Perry Lake	26 km NE	0.07	0.05	0.06
Garbe Lake	30 km NE	0.04	0.05	0.04
Goudreau	35 km NE	0.09	0.10	0.07
Troupe Lake	40 km NE	0.02	0.04	0.03
Dubreuil Road	45 km NNE	0.03	0.04	0.03
Lucy Pit	12 km ENE	0.09	0.06	0.07
Hawk Junction	21 km E	0.03	0.02	0.04
Highway 17	1.6 km SW	0.10	0.07	0.06
Mission Road	8.0 km SSW	0.03	0.01	0.01
Michipicoten Harbour	9.0 km SW	0.04	0.03	0.02
Obatanga Park	56 km NW	0.01	0.01	0.02
Government Rd. Wawa	0.5 km SE	0.10	0.04	0.06
Wawa Park	1.6 km SE	0.07	0.03	0.03
Beck Public School	2.2 km SE	0.03	0.02	0.01
Centennial Park	1.7 km SSE	0.05	0.03	0.01

Table 58

Concentrations of Iron (%) in Soil Samples

Collected in the Wawa Area Arsenic Study in 1975

Site	Location	Depth of sample (cm) 0-5	5-10	10-15
Site 1	1.1 km N	8.56	11.00	3.91
Site 2	2.2 km NE	7.55	3.24	3.23
Site 3	4.2 km NE	3.60	4.92	4.46
Site 4	6.3 km NE	2.89	2.19	1.95
Site 5	7.7 km NE	2.75	2.12	2.41
Site 6	10.8 km NE	1.50	1.90	1.90
Site 7	13.8 km NE	1.65	1.59	2.52
Parks Lake	16 km NE	2.59	2.66	2.97
Finger Lake	19 km NE	0.97	2.43	2.82
Perry Lake	26 km NE	1.26	1.79	1.85
Garbe Lake	30 km NE	0.89	1.19	1.37
Goudreau	35 km NE	3.85	4.16	4.18
Troupe Lake	40 km NE	1.13	1.48	1.47
Dubreuil Road	45 km NNE	1.08	1.30	1.36
Lucy Pit	12 km ENE	1.68	2.11	2.38
Hawk Junction	21 km E	1.26	1.08	0.94
Highway 17	1.6 km SW	4.07	2.55	2.58
Mission Road	8.0 km SSW	0.83	0.76	0.79
Michipicoten Harbour	9.0 km SW	0.76	0.57	0.55
Obatanga Park	56 km NW	0.10	0.09	0.06
Government Rd. Wawa	0.5 km SE	16.10	2.17	1.80
Wawa Park	1.6 km SE	1.08	1.34	1.06
Beck Public School	2.2 km SE	0.95	0.83	0.78
Centennial Park	1.7 km SSE	1.19	1.06	0.92

Concentrations of Manganese (ug/g) in Soil Samples

Collected in the Wawa Area Arsenic Study in 1975

Site	Location	Depth of sample (cm) 0-5	5-10	10-15
Site 1	1.1 km N	2598	1415	488
Site 2	2.2 km NE	1433	333	294
Site 3	4.2 km NE	376	154	145
Site 4	6.3 km NE	376	227	172
Site 5	7.7 km NE	549	225	205
Site 6	10.8 km NE	177	69	82
Site 7	13.8 km NE	182	75	94
Parks Lake	16 km NE	231	292	226
Finger Lake	19 km NE	116	64	83
Perry Lake	26 km NE	70	41	43
Garbe Lake	30 km NE	83	74	74
Goudreau	35 km NE	580	627	523
Troupe Lake	40 km NE	74	74	62
Dubreuil Road	45 km NNE	322	221	167
Lucy Pit	12 km ENE	267	79	115
Hawk Junction	21 km E	162	144	124
Highway 17	1.6 km SW	5110	501	220
Mission Road	8.0 km SSW	123	87	89
Michipicoten Harbour	9.0 km SW	161	103	78
Obatanga Park	56 km NW	26	13	19
Government Rd. Wawa	0.5 km SE	7610	702	274
Wawa Park	1.6 km SE	309	133	145
Beck Public School	2.2 km SE	113	53	57
Centennial Park	1.7 km SSE	170	125	115

Table 60

Concentrations of Zinc (ug/g) in Soil Samples

Collected in the Wawa Area Arsenic Study in 1975

Site	Location	Depth of sample (cm) 0-5	5-10	10-15
Site 1	1.1 km N	37	36	33
Site 2	2.2 km NE	36	32	35
Site 3	4.2 km NE	34	48	44
Site 4	6.3 km NE	45	45	41
Site 5	7.7 km NE	37	37	41
Site 6	10.8 km NE	33	42	52
Site 7	13.8 km NE	39	36	49
Parks Lake	16 km NE	126	52	56
Finger Lake	19 km NE	59	33	35
Perry Lake	26 km NE	28	27	24
Garbe Lake	30 km NE	27	22	26
Goudreau	35 km NE	75	70	69
Troupe Lake	40 km NE	38	27	25
Dubreuil Road	45 km NNE	50	48	45
Lucy Pit	12 km ENE	42	34	41
Hawk Junction	21 km E	43	40	43
Highway 17	1.6 km SW	64	40	45
Mission Road	8.0 km SSW	31	32	30
Michipicoten Harbour	9.0 km SW	55	55	45
Obatanga Park	56 km NW	21	18	12
Government Rd. Wawa	0.5 km SE	59	35	38
Wawa Park	1.6 km SE	41	32	37
Beck Public School	2.2 km SE	30	24	21
Centennial Park	1.7 km SSE	38	34	32

Table 61

Concentrations of Copper (ug/g) in Soil Samples

Collected in the Wawa Area Arsenic Study in 1975

Site	Location	Depth of sample (cm) 0-5	5-10	10-15
Site 1	1.1 km N	10	12	9
Site 2	2.2 km NE	16	17	23
Site 3	4.2 km NE	11	23	24
Site 4	6.3 km NE	36	27	38
Site 5	7.7 km NE	12	11	10
Site 6	10.8 km NE	9	9	9
Site 7	13.8 km NE	19	9	15
Parks Lake	16 km NE	20	23	21
Finger Lake	19 km NE	13	21	34
Perry Lake	26 km NE	19	8	9
Garbe Lake	30 km NE	19	14	20
Goudreau	35 km NE	56	63	54
Troupe Lake	40 km NE	12	9	10
Dubreuil Road	45 km NNE	7	7	7
Lucy Pit	12 km ENE	17	15	34
Hawk Junction	21 km E	20	19	13
Highway 17	1.6 km SW	27	13	14
Mission Road	8.0 km SSW	9	8	9
Michipicoten Harbour	9.0 km SW	14	13	10
Obatanga Park	56 km NW	5	4	3
Government Rd. Wawa	0.5 km SE	18	9	7
Wawa Park	1.6 km SE	7	5	5
Beck Public School	2.2 km SE	6	6	5
Centennial Park	1.7 km SSE	9	11	9

Table 62

Concentrations of Calcium (ug/g) in Soil Samples

Collected in the Wawa Area Arsenic Study in 1975

Site	Location	Depth of sample (cm) 0-5	5-10	10-15
Site 1	1.1 km N	227	87	237
Site 2	2.2 km NE	183	380	347
Site 3	4.2 km NE	820	567	510
Site 4	6.3 km NE	500	343	680
Site 5	7.7 km NE	490	557	477
Site 6	10.8 km NE	490	510	437
Site 7	13.8 km NE	870	403	443
Parks Lake	16 km NE	427	420	407
Finger Lake	19 km NE	263	262	217
Perry Lake	26 km NE	393	180	121
Garbe Lake	30 km NE	1093	859	871
Goudreau	35 km NE	2693	2010	1943
Troupe Lake	40 km NE	1070	863	1284
Dubreuil Road	45 km NNE	1028	1263	1960
Lucy Pit	12 km ENE	747	373	729
Hawk Junction	21 km E	3600	2300	1900
Highway 17	1.6 km SW	1600	1158	955
Mission Road	8.0 km SSW	770	600	800
Michipicoten Harbour	9.0 km SW	4300	5400	5600
Obatanga Park	56 km NW	315	173	245
Government Rd. Wawa	0.5 km SE	503	413	290
Wawa Park	1.6 km SE	456	911	839
Beck Public School	2.2 km SE	700	500	400
Centennial Park	1.7 km SSE	4300	2700	2400

Table 63

Concentrations of Magnesium (%) in Soil Samples

Collected in the Wawa Area Arsenic Study in 1975

Site	Location	Depth of sample (cm) 0-5	5-10	10-15
Site 1	1.1 km N	0.69	0.42	0.27
Site 2	2.2 km NE	0.43	0.27	0.30
Site 3	4.2 km NE	0.46	1.18	1.25
Site 4	6.3 km NE	0.32	0.22	0.28
Site 5	7.7 km NE	0.17	0.16	0.22
Site 6	10.8 km NE	0.13	0.16	0.16
Site 7	13.8 km NE	0.18	0.16	0.22
Parks Lake	16 km NE	0.22	0.22	0.23
Finger Lake	19 km NE	0.07	0.11	0.13
Perry Lake	26 km NE	0.08	0.10	0.10
Garbe Lake	30 km NE	0.11	0.14	0.14
Goudreau	35 km NE	0.90	0.94	0.92
Troupe Lake	40 km NE	0.11	0.15	0.13
Dubreuil Road	45 km NNE	0.16	0.16	0.20
Lucy Pit	12 km ENE	0.17	0.20	0.30
Hawk Junction	21 km E	0.37	0.32	0.25
Highway 17	1.6 km SW	0.68	0.28	0.25
Mission Road	8.0 km SSW	0.09	0.09	0.09
Michipicoten Harbour	9.0 km SW	0.35	0.33	0.37
Obatanga Park	56 km NW	0.02	0.01	0.03
Government Rd. Wawa	0.5 km SE	1.54	0.20	0.16
Wawa Park	1.6 km SE	0.11	0.13	0.10
Beck Public School	2.2 km SE	0.07	0.06	0.07
Centennial Park	1.7 km SSE	0.22	0.22	0.16

Table 64

pH of Soil Samples

Collected in the Wawa Area Arsenic Study in 1975

Site	Location	Depth of sample (cm) 0-5	5-10	10-15
Site 1	1.1 km N	4.3	4.5	4.7
Site 2	2.2 km NE	3.8	4.2	4.4
Site 3	4.2 km NE	3.9	4.3	4.3
Site 4	6.3 km NE	4.2	4.4	4.5
Site 5	7.7 km NE	4.0	4.2	4.3
Site 6	10.8 km NE	3.8	4.2	4.5
Site 7	13.8 km NE	4.1	4.5	4.7
Parks Lake	16 km NE	4.7	5.1	4.8
Finger Lake	19 km NE	3.7	4.4	4.8
Perry Lake	26 km NE	4.0	4.6	4.7
Garbe Lake	30 km NE	4.2	4.8	5.1
Goudreau	35 km NE	5.2	5.1	5.2
Troupe Lake	40 km NE	4.4	5.0	5.0
Dubreuil Road	45 km NNE	5.0	5.2	5.3
Lucy Pit	12 km ENE	4.0	4.6	5.3
Hawk Junction	21 km E	6.4	6.7	6.4
Highway 17	1.6 km SW	5.2	4.9	5.0
Mission Road	8.0 km SSW	5.4	5.4	5.7
Michipicoten Harbour	9.0 km SW	6.5	6.5	6.5
Obatanga Park	56 km NW	4.2	4.6	5.0
Government Rd. Wawa	0.5 km SE	5.5	5.2	5.1
Wawa Park	1.6 km SE	5.0	5.2	5.3
Beck Public School	2.2 km SE	5.2	5.2	5.7
Centennial Park	1.7 km SSE	6.5	6.6	6.6

Table 65

Concentrations of Various Chemical Components of Snow Samples

Collected in the Wawa Area - 1975-1976

Site	Location	Year	SO_4	Fe	As	Zn	Ca	Mg	Na	Cl	Pb	pH	Alkalinity
ACR 1/2	0.8 km NE	1975	7.2	14.8	95	.06	4.1	.5	.4	1.3	.02	-	8
ACR 1	1.6 km NE	1976	5.6	4.2	41	.02	2.8	.4	.5	1.1	.03	-	6
Lucy Pit	12 km ENE	1975	2.0	.9	5	-	.3	-	.3	.8	-	4.4	-
		1976	1.8	1.0	6	.02	.4	.1	.2	.4	.02	-	1
Wawa Lake	1.6 km E	1975	1.0	5.0	18	-	1.4	-	.8	1.9	-	5.2	-
		1976	3.8	3.4	24	.04	1.7	.2	1.1	1.9	.04	-	4
Hawk Junction	21.3 km E	1975	1.0	.6	ND	-	.1	-	.2	.4	-	4.5	-
		1976	1.4	.3	2	.06	.5	.1	.5	1.5	.01	-	1
Government Road	.5 km SE	1975	6.0	11.0	32	-	2.8	-	.6	1.7	-	6.0	-
		1976	-	16.0	-	.04	1.2	.2	-	-	.05	-	6
Queens Park	1.4 km SE	1975	3.0	4.1	17	-	1.0	-	.6	1.2	-	5.3	-
		1976	-	-	-	.02	1.9	.2	-	-	.04	-	4
Centennial Park	1.7 km SSE	1976	2.3	1.0	7	.02	.8	.1	.1	.3	.02	-	4
Beck Public School	2.2 km SE	1976	3.2	2.3	17	.02	1.3	.2	.4	.1	.02	-	3
Highway 17	1.6 km SW	1975	16.0	88.0	230	-	12.0	-	4.3	7.6	-	5.2	-
		1976	2.4	14.8	36	.06	1.9	.4	3.1	5.3	.02	-	6
Mission Road	8.0 km SSW	1975	4.0	4.8	21	-	.9	-	.3	.7	-	4.9	-
		1976	3.9	.5	38	.03	1.6	.2	.4	.8	.02	-	5
Michipicoten	9.0 km SW	1975	5.0	5.0	21	-	1.0	-	2.1	2.3	-	4.9	-
		1976	1.7	.3	9	.01	4.6	.1	.5	.8	.01	-	11
Control	-	1976	1.0	.2	2	.01	.3	.1	2.7	4.4	.03	-	0

TABLE A
SELECTED CHEMICAL ANALYSES
WAWA AREA LAKES 1971-72

LAKE	#	DATE	pH	ALK. as $CaCO_3$	HARD. as $CaCO_3$	Ca	Mg	Na	K	SiO_2	SO_4	Cl	# of Samples
Moran	2	10/06/72	7.5	30	296	36	50	3	.60	.20	227	6.4	(13)
Lagarde	3	01/09/71	3.5	0	63	17	4.5	1	.65	3.50	101	1.0	(2)
Arliss	4	23/07/71	8.0	18	42	14	1.0	2	.60	.60	20	2.0	(1)
Mildred	6	13/03/72	7.3	39	70	23	3.0	1	.90	3.30	27	<1.0	(1)
Brooks	7	06/08/71	8.0	48	182	47	16.0	3	1.10	2.30	133	3.0	(1)
Loonskin	8	01/09/71	6.6	21	38	14	<1.0	<1	.45	.40	20	1.5	(2)
Bauldry	9	31/07/71	7.0	20	33	11	<1.0	<1	.35	1.80	17	<1.0	(2)
Garbe	10	25/08/71	7.4	28	39	14	1.0	1	.50	.50	18	1.0	(1)
Goetz	11	19/08/71	7.5	33	58	20	2.0	1	.70	1.70	25	2.0	(2)
West Andre	12	30/07/71	7.9	26	50	18	1.0	1	.60	.40	28	1.0	(1)
Hawk	13	01/09/71	6.9	36	52	17	2.0	<1	.60	2.90	18	1.0	(2)
Parks	14	19/08/71	7.6	26	54	16	3.0	1	.60	2.70	29	2.0	(3)
Andre	15	21/07/71	8.0	36	64	22	2.0	2	.60	.70	21	4.0	(1)
Wallace	17	28/07/71	8.0	40	64	22	2.0	1	.60	3.60	18	1.0	(1)
Perry	18	06/03/72	7.5	27	45	15	3.0	1	.20	1.90	17	<1.0	(2)
Pivot	19	01/09/71	7.2	8	16	6	<1.0	<1	.40	.40	12	1.0	(2)
Selkirk	20	05/08/71	7.8	26	40	14	1.0	1	.30	1.40	10	1.0	(1)
Billboy	21	31/08/71	7.0	21	35	12	1.0	<1	.40	2.40	18	<1.0	(3)
Morrison	23	26/08/71	7.4	32	43	15	1.0	1	.40	2.70	13	2.0	(2)
Troupe	24	01/09/71	7.1	17	29	9	1.0	<1	.40	1.00	12	1.0	(3)
Maskinonge	26	31/08/71	7.1	23	34	11	1.0	1	.30	1.30	15	1.0	(2)
Swanson	27	01/09/71	6.1	24	33	10	1.0	<1	.30	1.30	13	1.0	(1)
Clearview	31	01/09/71	7.1	17	24	9	<1.0	<1	.60	.60	12	1.0	(2)
Goldie	32	28/10/71	7.6	20	28	9	1.0	<1	.40	2.40	14	2.0	(2)

Values represent means of surface water samples
Values for conductivity in $\mu mhos/cm^{-1}$
All other data except pH in mg/l

TABLE B

SELECTED CHEMICAL ANALYSES

WAWA AREA LAKES 1975

LAKE	#	DATE	pH	COND.	ALK. as $CaCO_3$	HARD. as $CaCO_3$	Ca	Mg	Na	K	SiO_2	SO_4	Cl
Wawa	1	16/09/75	7.6	150	40	70	21.0	4.45	1.7	.60	1.0	28	3.0
Lagarde	3	16/09/75	3.4	300	< 1	63	18.0	4.60	.70	1.05	1.8	100	.6
Arliss	4	16/09/75	7.1	45	16	40	13.0	1.80	.50	.40	.3	25	.3
Lena	5	16/09/75	7.5	115	30	53	17.0	2.60	.50	.45	.6	20	.5
Mildred	6	16/09/75	7.7	180	34	79	25.0	4.20	.70	.85	.9	50	.3
Loonskin	8	17/09/75	7.5	90	19	38	13.0	1.50	.40	.55	.4	20	.3
Goetz	11	17/09/75	7.6	125	31	59	19.5	2.55	.50	.55	2.3	28	.3
Hawk	13	17/09/75	7.6	120	36	56	18.5	2.40	.80	.75	1.9	15	.8
Andre	15	17/09/75	7.5	125	31	61	20.0	2.65	.60	.60	.5	27	.3
Finger	16	17/09/75	7.0	85	13	35	11.0	1.95	.50	.50	.6	23	.3
Perry	18	17/09/75	7.1	90	24	41	12.0	2.65	.70	.80	.8	17	.2
Billboy	21	17/09/75	7.1	75	19	35	10.5	2.20	.30	.45	1.0	14	.3
Summit	22	17/09/75	6.8	245	31	91	34.0	1.45	.40	.20	1.9	---	1.6
Herman	25	17/09/75	7.6	105	38	33	11.0	1.45	.50	.35	1.1	14	.3
Dog	28	17/09/75	7.4	85	31	48	16.0	1.90	1.30	.90	1.1	9	.3
Black Trout	29	17/09/75	6.9	47	9	18	5.5	.95	.60	.55	1.6	10	.4
Catfish	30	17/09/75	7.3	89	21	32	10.5	1.40	1.60	.70	1.2	8	2.5

Values represent single surface water samples
Values for conductivity in µmho/cm
All other data except pH in mg/l.

TABLE C

SELECTED METALS ANALYSES

WAWA AREA LAKES 1975

Table 68

LAKE	#	DATE	ZINC	COPPER	NICKEL	LEAD	CADMIUM	IRON	ARSENIC
Wawa	1	16/09/75	< 3	< 3	< 3	< 3	< 1	7	1
Lagarde	3	16/09/75	62	6	5	7	< 1	55	4
Arliss	4	16/09/75	< 3	< 3	< 3	< 3	< 1	8	5
Lena	5	16/09/75	< 3	< 3	< 3	< 3	< 1	10	2.5
Mildred	6	16/09/75	< 3	< 3	< 3	< 3	< 1	19	9
Loonskin	8	17/09/75	< 3	< 3	< 3	< 3	< 1	27	2
Goetz	11	17/09/75	< 3	< 3	< 3	< 3	< 1	22	4.5
Hawk	13	17/09/75	6	< 3	< 3	< 3	< 1	21	< 1
Andre	15	17/09/75	< 3	< 3	< 3	< 3	< 1	17	4
Finger	16	17/09/75	< 3	< 3	< 3	< 3	< 1	28	3
Perry	18	17/09/75	< 3	< 3	< 3	< 3	< 1	48	1.5
Billboy	21	17/09/75	< 3	< 3	< 3	< 3	< 1	22	2
Summit	22	17/09/75	16	< 3	< 3	< 3	< 1	14	1
Herman	25	17/09/75	18	< 3	< 3	< 3	< 1	100	1
Dog	28	17/09/75	< 3	< 3	< 3	< 3	< 1	12	< 1
Black Trout	29	17/09/75	< 3	< 3	< 3	< 3	< 1	14	1.5
Catfish	30	17/09/75	< 3	< 3	< 3	< 3	< 1	36	<1

values represent single surface water samples (ug/l)

TABLE D

ANALYSES OF BOTTOM SEDIMENTS

WAWA AREA LAKES, 1975

LAKE	#	DATE	ZINC	COPPER	NICKEL	LEAD	CADMIUM	IRON	ARSENIC	TOTAL NITROGEN	TOTAL PHOSPHORUS	LOSS ON IGNITION
Wawa	1	16/09/75	66	18	16	27	.5	18.2	38.0	1.2	.76	4.3
Lagarde	3	16/09/75	100	23	21	20	1.2	31.2	260.0	.99	.58	3.9
Arliss	4	16/09/75	190	64	31	130	3.9	31.5	120.0	12.0	1.3	36.0
Lena	5	16/09/75	120	79	84	40	1.8	28.2	65.0	16.0	1.2	45.0
Mildred	6	16/09/75	150	96	110	58	1.8	49.2	250.0	13.0	1.1	37.0
Loonskin	8	17/09/75	230	79	28	86	4.2	66.0	100.0	13.0	1.9	38.0
Goetz	11	17/09/75	230	100	62	98	3.4	73.0	210.0	10.0	1.6	36.0
Hawk	13	17/09/75	97	42	22	9	.7	19.5	4.2	5.0	1.8	17.0
Andre	15	17/09/75	230	54	20	110	2.4	42.0	220.0	14.0	1.6	39.0
Finger	16	17/09/75	360	64	14	130	3.8	190.0	580.0	17.0	1.3	39.0
Perry	18	17/09/75	190	74	16	100	2.7	24.5	28.0	16.0	1.5	46.0
Billboy	21	17/09/75	130	32	13	69	2.2	13.5	12.0	15.0	1.1	51.0
Herman	25	17/09/75	100	38	14	58	1.2	17.0	30.0	13.0	1.1	41.0
Dog	28	17/09/75	120	29	30	54	1.4	41.0	24.0	4.8	2.1	17.0
Black Trout	29	17/09/75	140	34	59	3	1.6	47.1	17.0	.33	.69	5.3
Catfish	30	17/09/75	160	39	30	63	1.1	46.0	65.0	3.8	.99	16.0

Values for iron, phosphorus and nitrogen in mg/g
Values for loss on ignition in percent
All other data in µg/g

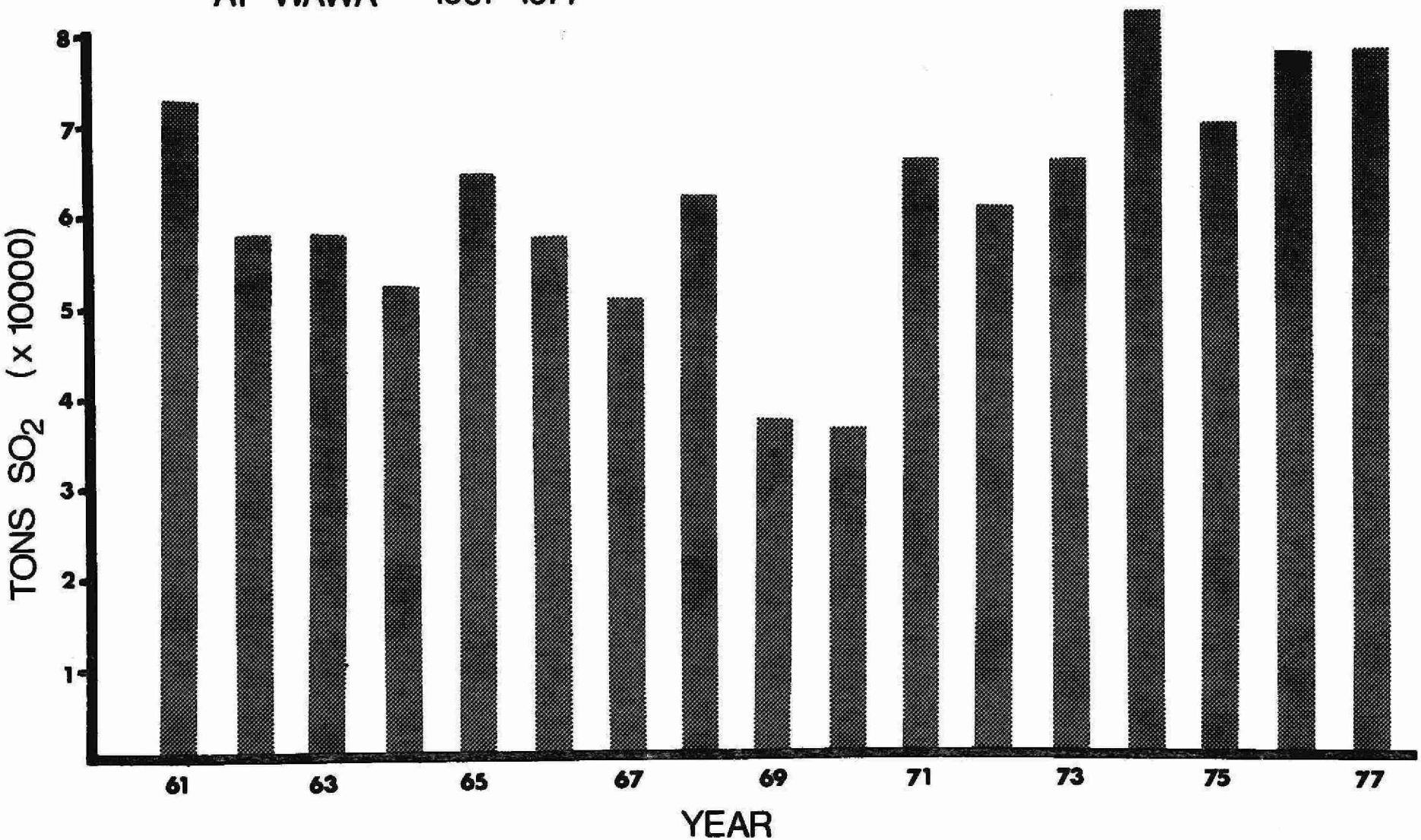
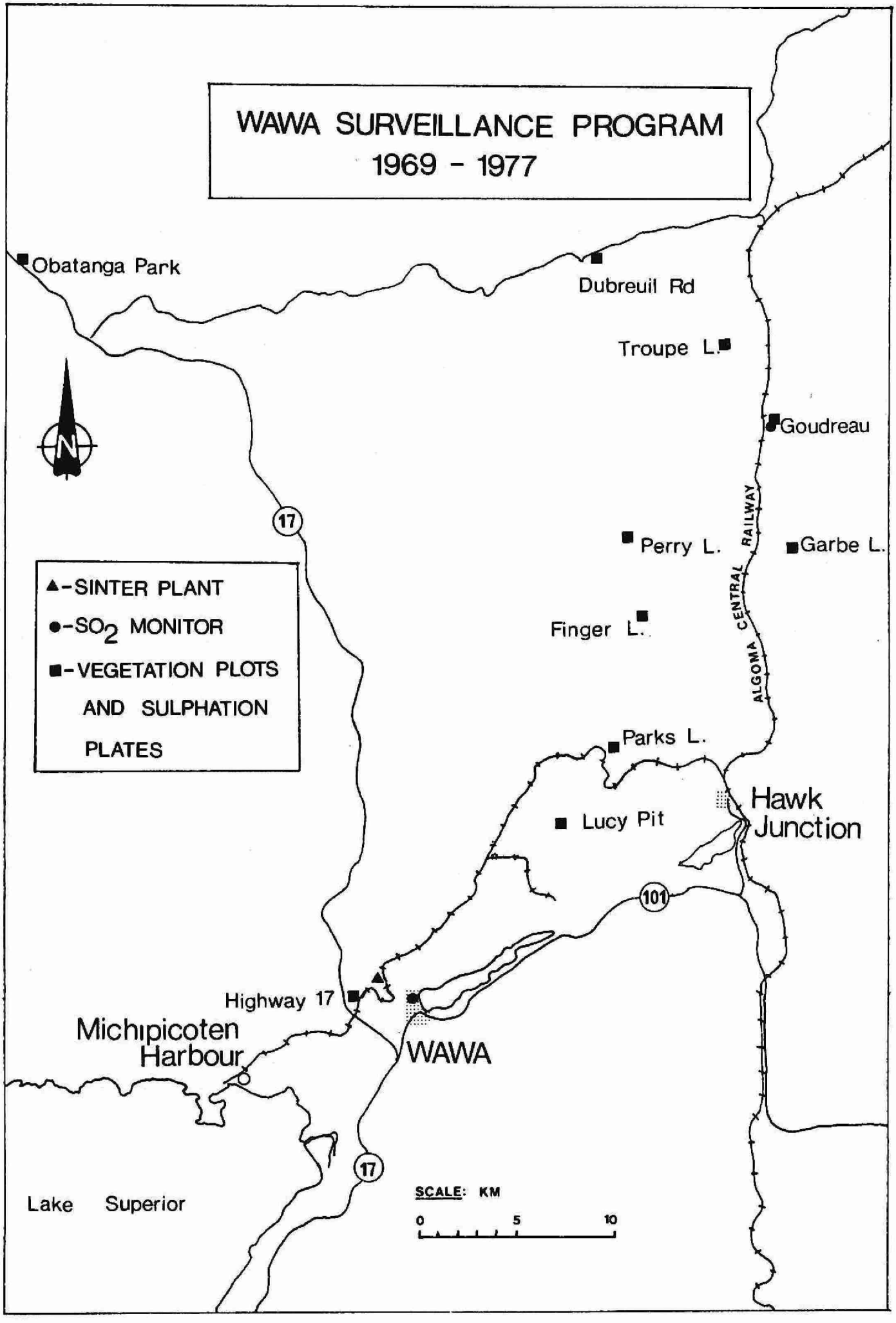

SULPHUR DIOXIDE EMISSIONS (MAY TO SEPTEMBER)
AT WAWA - 1961-1977
TONS SO_2 (x 10000)
8
7
6
5
4
3
2
1
61
63
65
67
69
71
73
75
77
YEAR

Figure 1

Figure 2


WAWA SURVEILLANCE PROGRAM
1969 - 1977
Obatanga Park
Dubreuil Rd
Troupe L.
Goudreau
N
17
Perry L.
Garbe L.
ALGOMA CENTRAL RAILWAY
▲-SINTER PLANT
●-SO2 MONITOR
■-VEGETATION PLOTS AND SULPHATION PLATES
Finger L.
Parks L.
Hawk Junction
Lucy Pit
101
Highway 17
Michipicoten Harbour
WAWA
17
Lake Superior
SCALE: KM
0
5
10

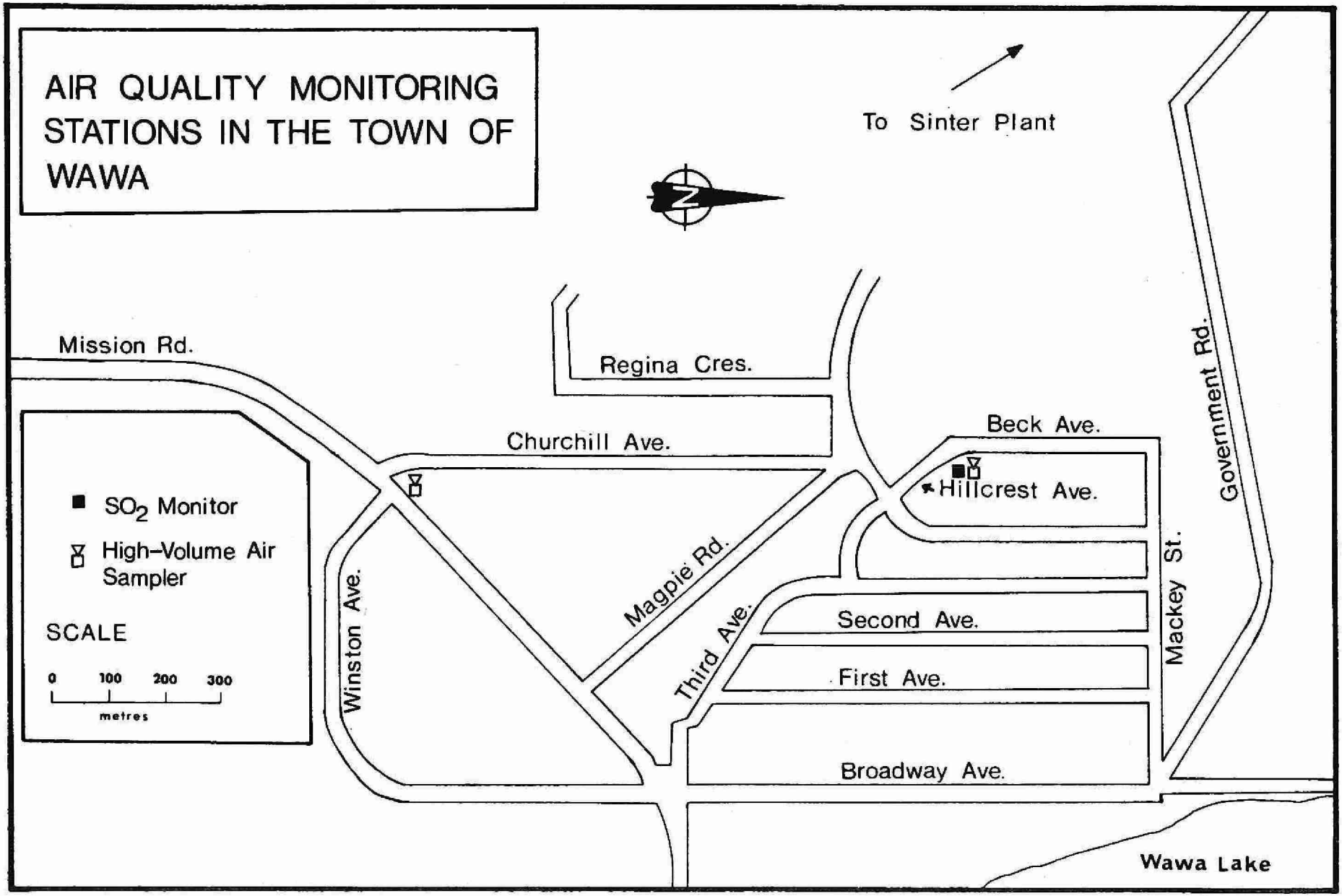

AIR QUALITY MONITORING STATIONS IN THE TOWN OF WAWA
To Sinter Plant
N
Mission Rd.
Regina Cres.
Churchill Ave.
Beck Ave.
Hillcrest Ave.
Government Rd.
Mackey St.
Magpie Rd.
Winston Ave.
Third Ave.
Second Ave.
First Ave.
Broadway Ave.
Wawa Lake
SO_2 Monitor
High-Volume Air Sampler
SCALE
0 100 200 300
metres

Figure 3

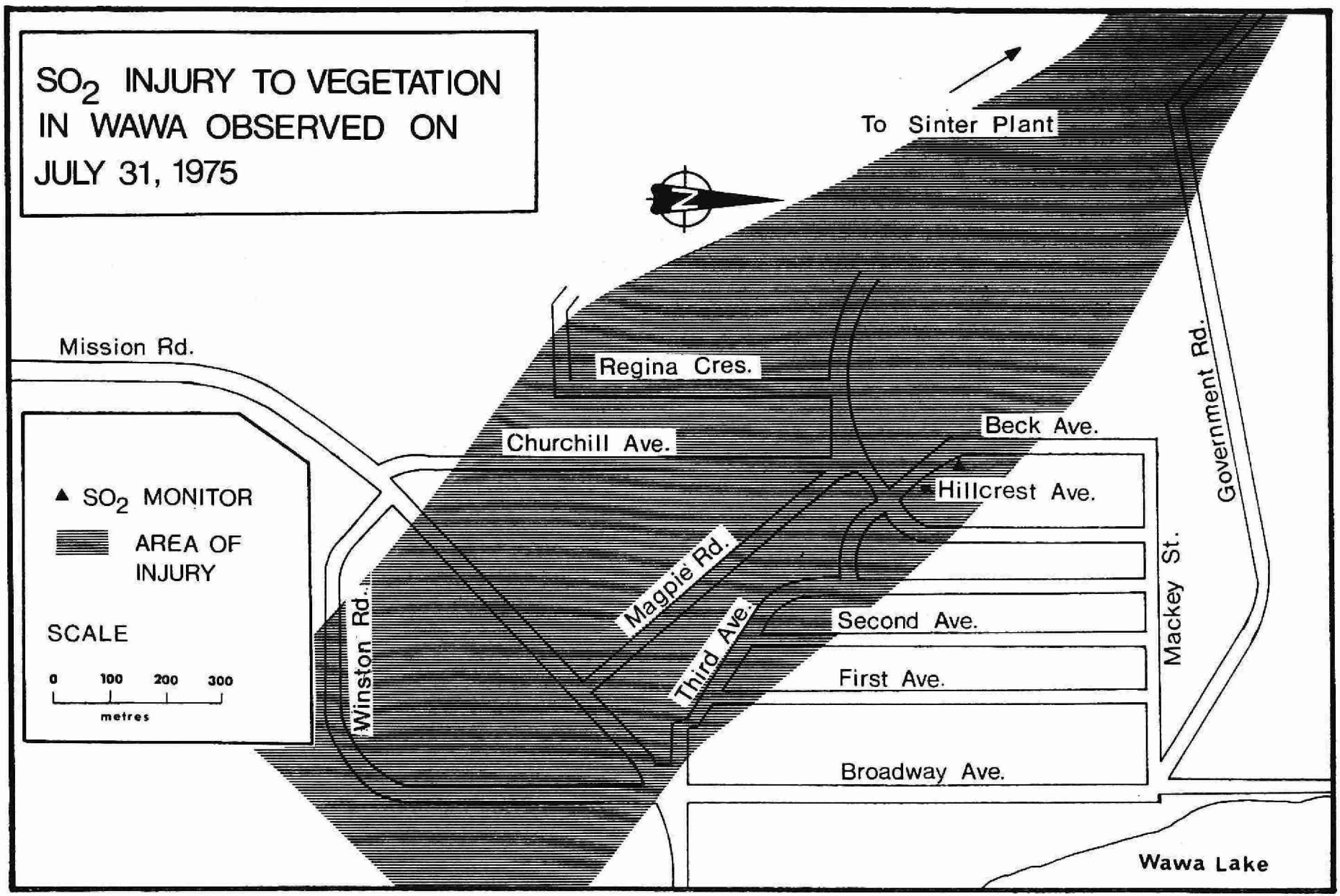

SO_2 INJURY TO VEGETATION IN WAWA OBSERVED ON JULY 31, 1975
To Sinter Plant
N
Mission Rd.
Regina Cres.
Churchill Ave.
Beck Ave.
Hillcrest Ave.
Government Rd.
Mackey St.
Magpie Rd.
Third Ave.
Second Ave.
First Ave.
Broadway Ave.
Winston Rd.
Wawa Lake
▲ SO_2 MONITOR
AREA OF INJURY
SCALE
0 100 200 300
metres

Figure 4

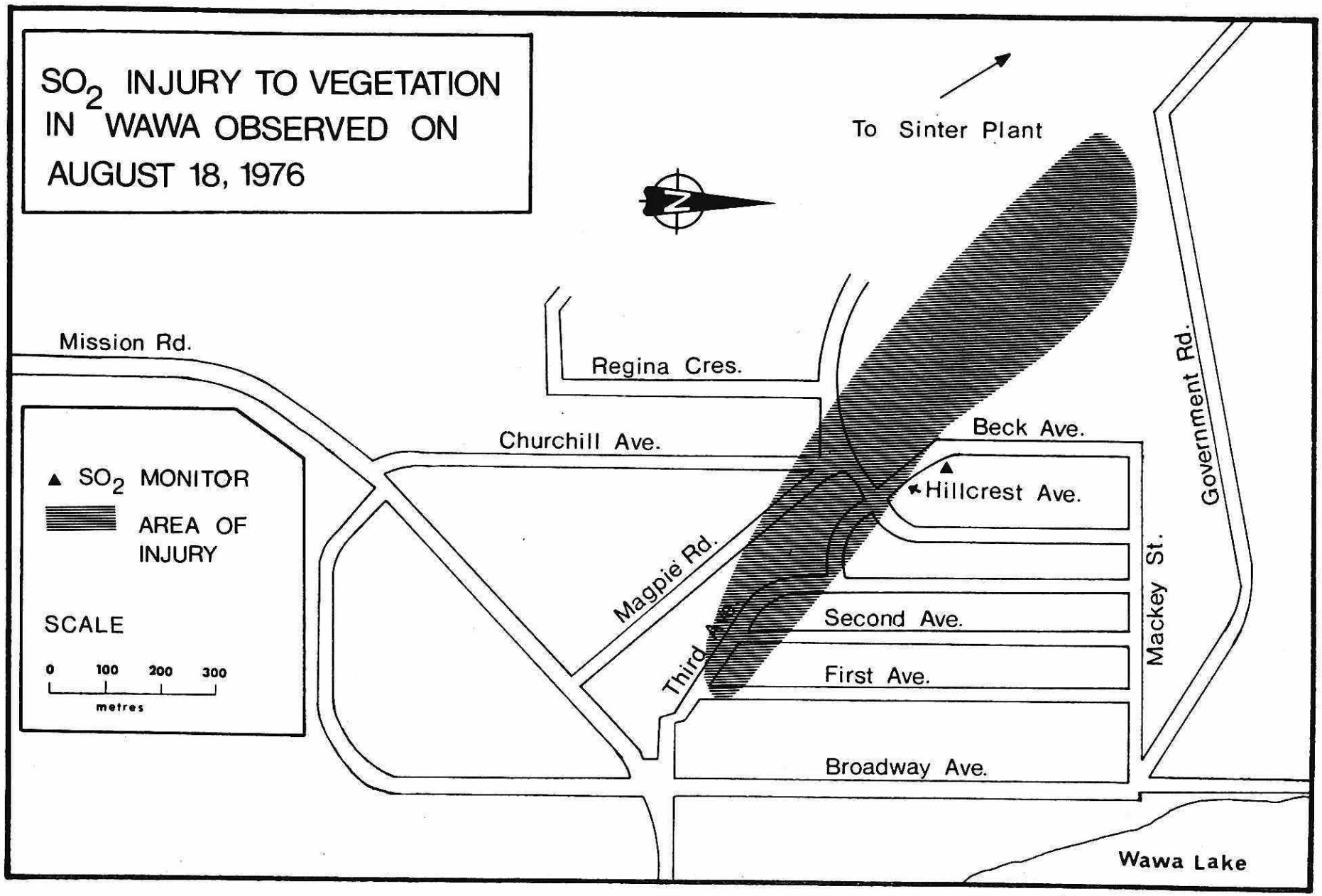

SO_2 INJURY TO VEGETATION IN WAWA OBSERVED ON AUGUST 18, 1976
To Sinter Plant
N
Mission Rd.
Regina Cres.
Churchill Ave.
Beck Ave.
Hillcrest Ave.
Government Rd.
Magpie Rd.
Third Ave.
Second Ave.
First Ave.
Mackey St.
Broadway Ave.
Wawa Lake
▲ SO_2 MONITOR
AREA OF INJURY
SCALE
0 100 200 300
metres

Figure 5

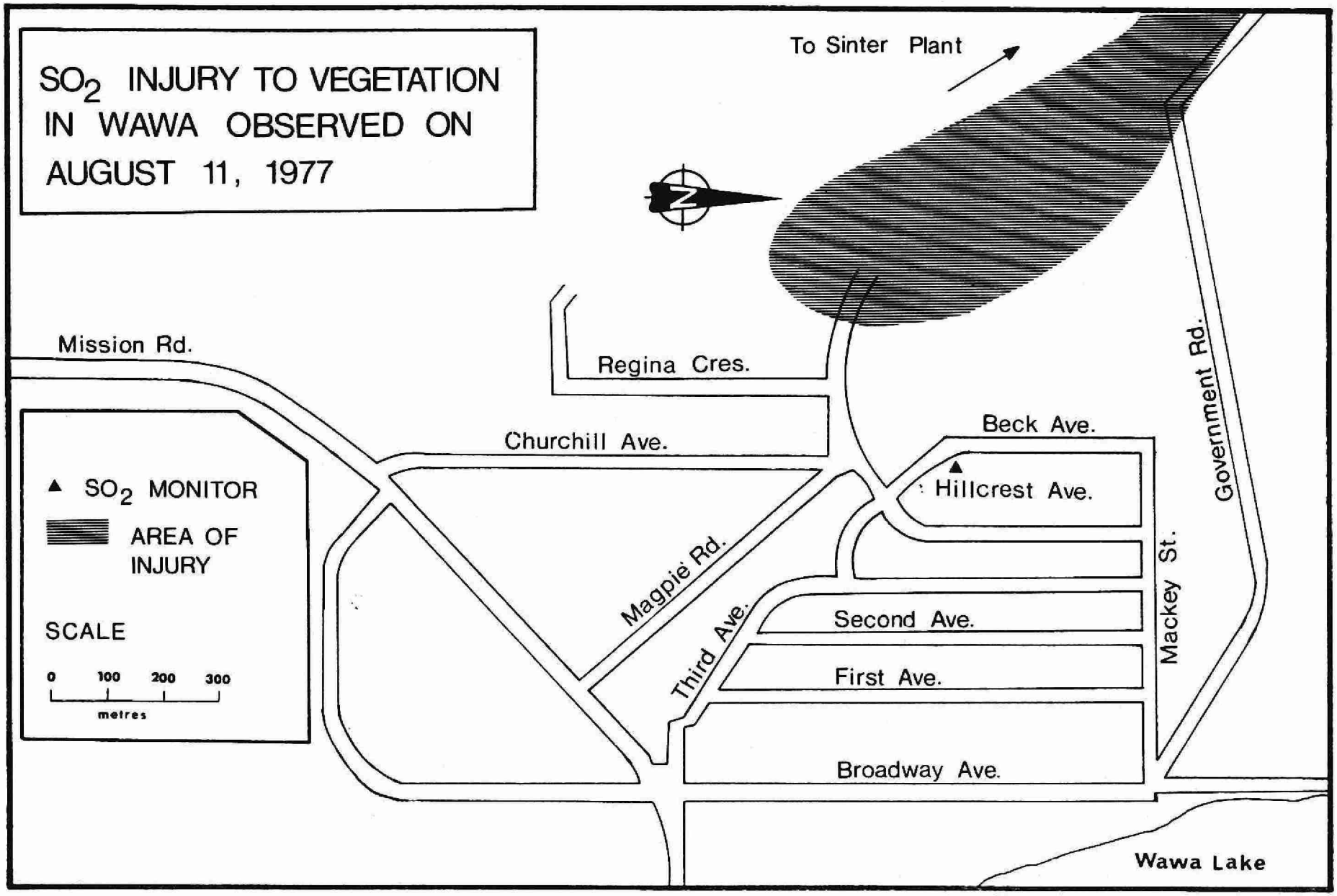
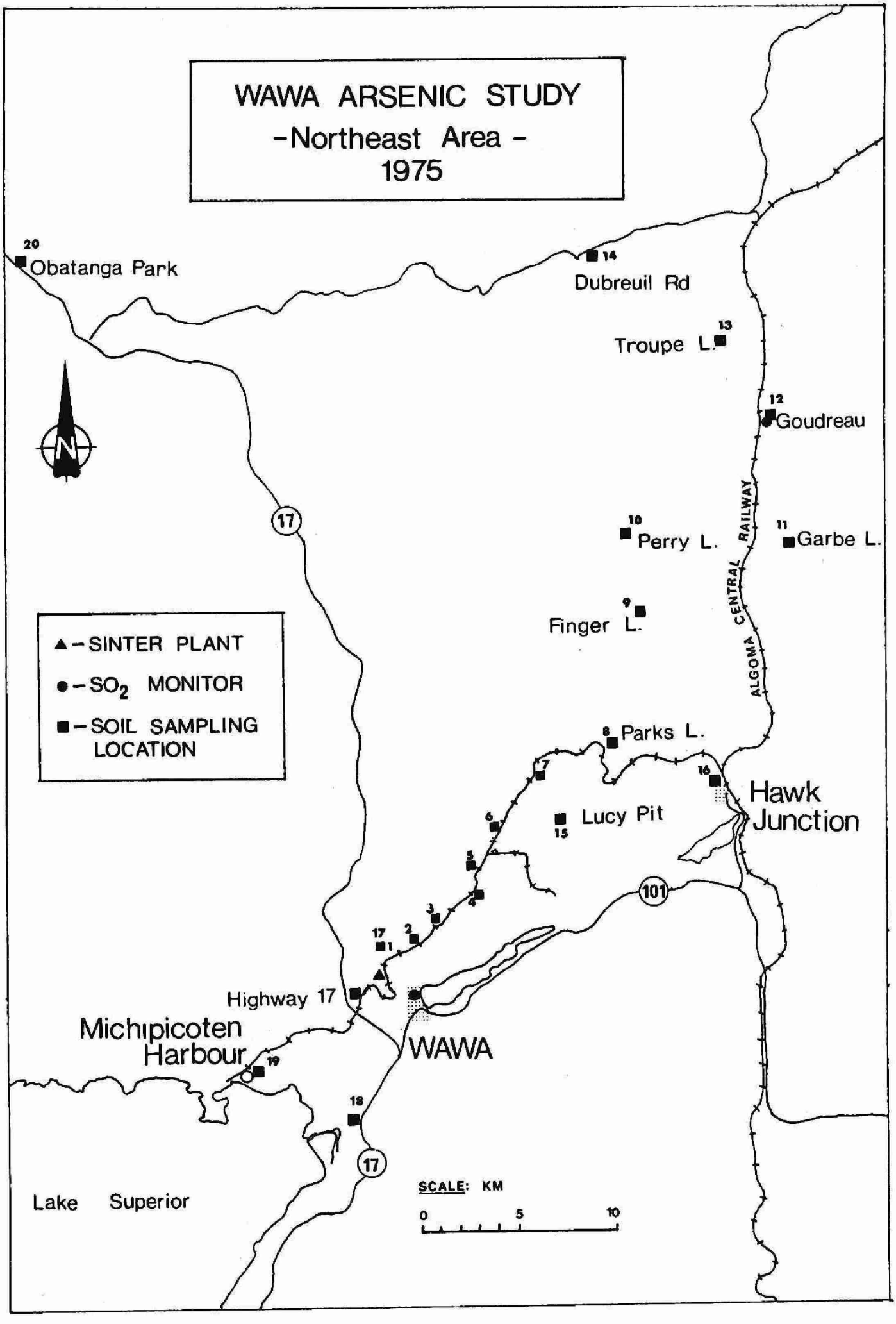

SO_2 INJURY TO VEGETATION IN WAWA OBSERVED ON AUGUST 11, 1977
To Sinter Plant
N
Mission Rd.
Regina Cres.
Churchill Ave.
Beck Ave.
Hillcrest Ave.
Government Rd.
Magpie Rd.
Third Ave.
Second Ave.
First Ave.
Mackey St.
Broadway Ave.
Wawa Lake
▲ SO_2 MONITOR
AREA OF INJURY
SCALE
0 100 200 300
metres

Figure 6

Figure 7


WAWA ARSENIC STUDY
-Northeast Area -
1975
20
Obatanga Park
14
Dubreuil Rd
13
Troupe L.
12
Goudreau
N
17
10
Perry L.
11
Garbe L.
RAILWAY
CENTRAL
ALGOMA
9
Finger L.
▲-SINTER PLANT
●-SO2 MONITOR
■-SOIL SAMPLING LOCATION
8
Parks L.
7
16
Hawk Junction
6
Lucy Pit
15
5
4
3
2
17
1
101
Highway 17
Michipicoten Harbour
19
WAWA
18
17
SCALE: KM
0
5
10
Lake Superior

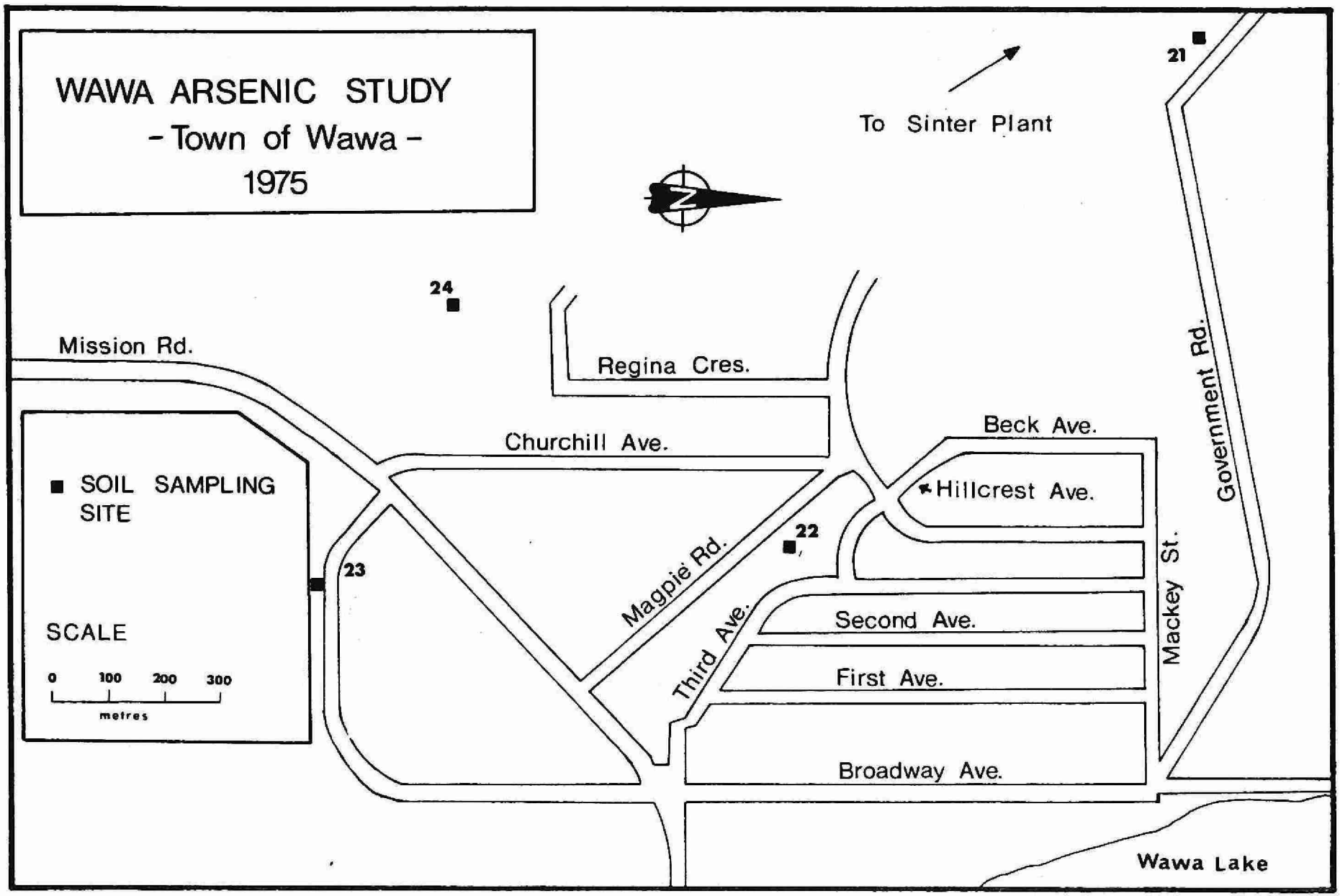
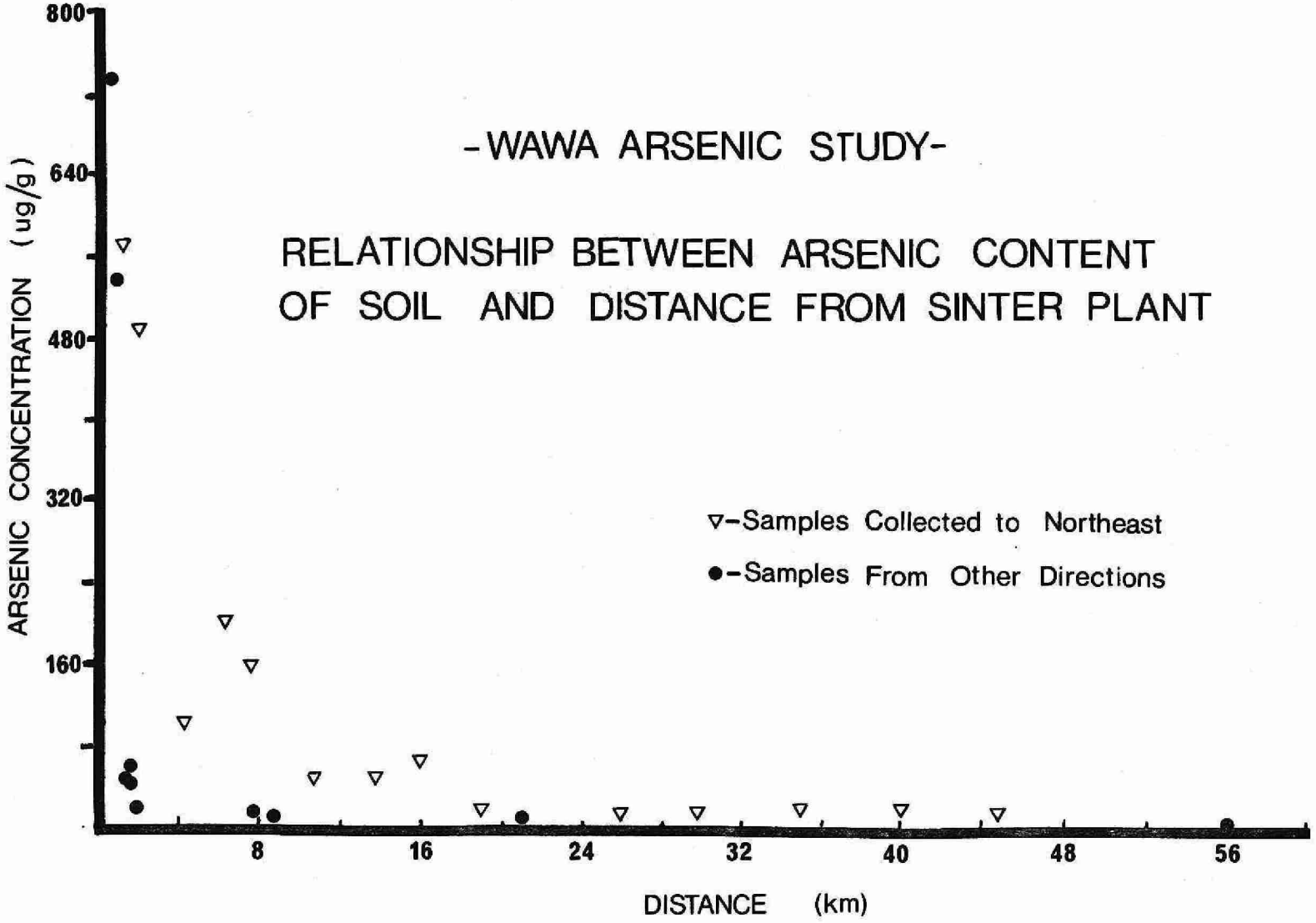

WAWA ARSENIC STUDY
- Town of Wawa -
1975
To Sinter Plant
N
21
24
Mission Rd.
Regina Cres.
Churchill Ave.
Beck Ave.
Government Rd.
Hillcrest Ave.
SOIL SAMPLING SITE
22
23
Magpie Rd.
Third Ave.
Mackey St.
Second Ave.
First Ave.
Broadway Ave.
SCALE
0 100 200 300
metres
Wawa Lake

Figure 8

Figure 9


-WAWA ARSENIC STUDY-
RELATIONSHIP BETWEEN ARSENIC CONTENT
OF SOIL AND DISTANCE FROM SINTER PLANT
ARSENIC CONCENTRATION (ug/g)
800
640
480
320
160
▽-Samples Collected to Northeast
●-Samples From Other Directions
8
16
24
32
40
48
56
DISTANCE (km)

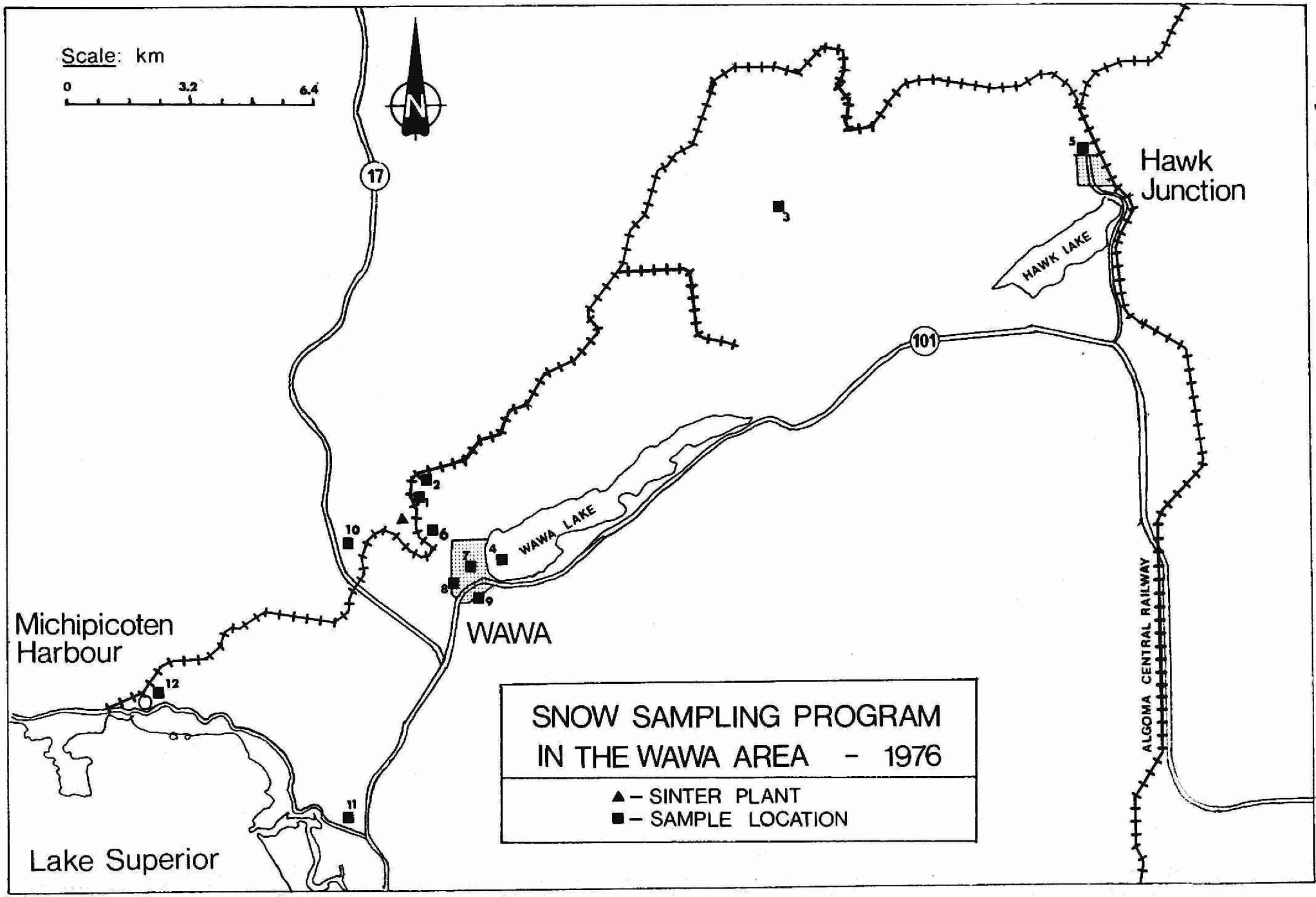

Scale: km
0
3.2
6.4
N
17
101
Hawk Junction
HAWK LAKE
WAWA LAKE
WAWA
Michipicoten Harbour
Lake Superior
ALGOMA CENTRAL RAILWAY
SNOW SAMPLING PROGRAM
IN THE WAWA AREA - 1976
▲ – SINTER PLANT
■ – SAMPLE LOCATION

Figure 10

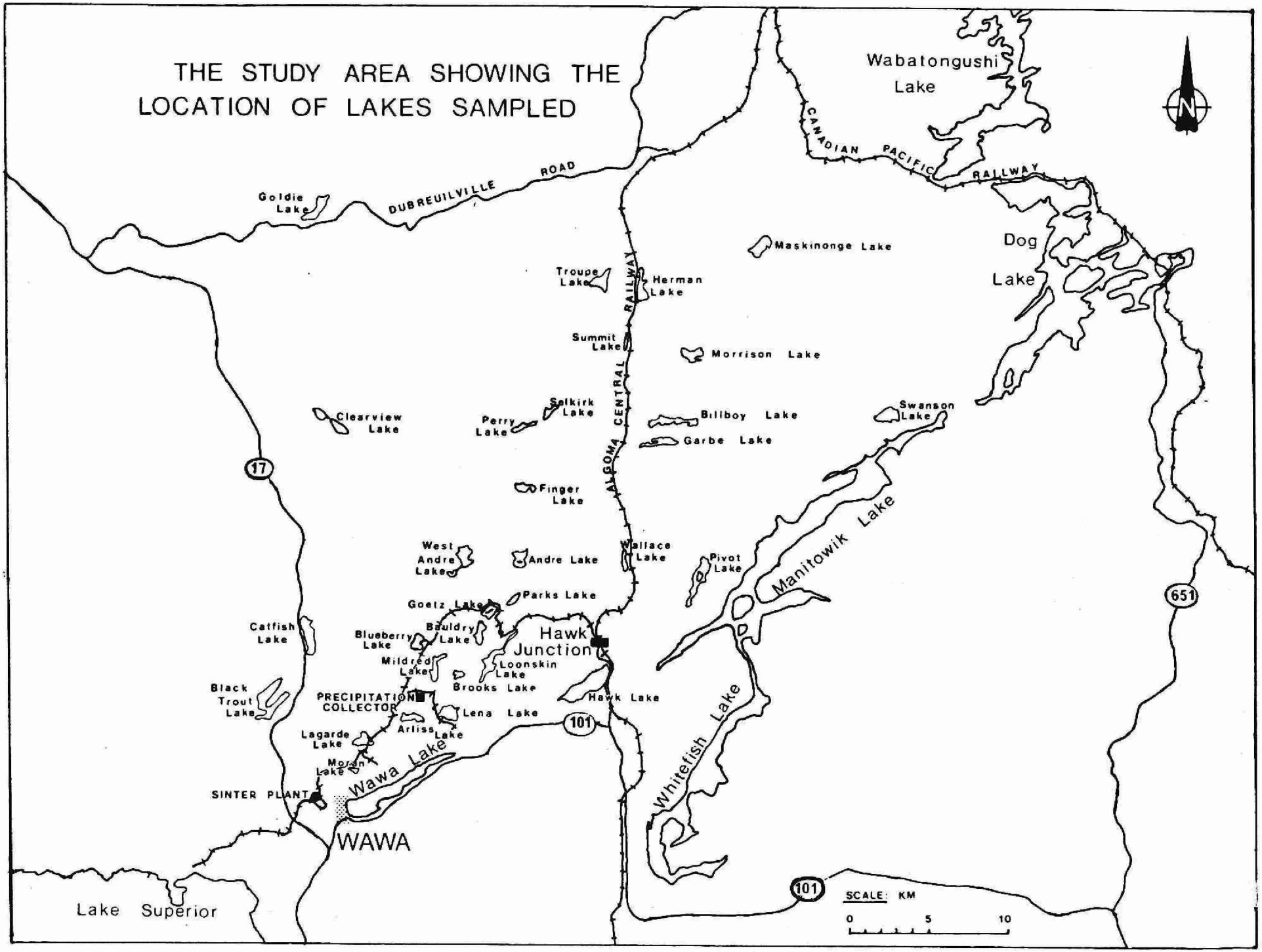
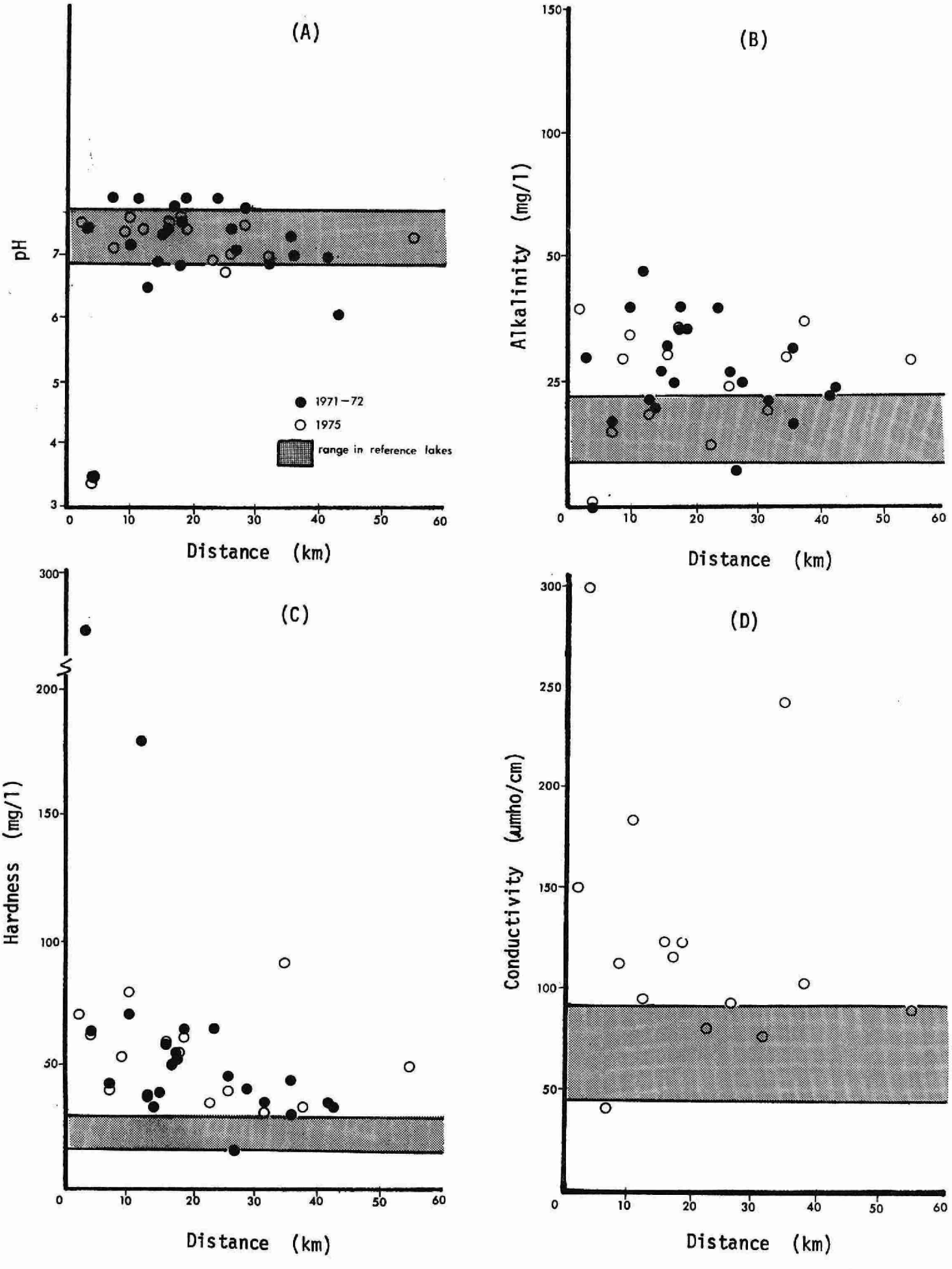

THE STUDY AREA SHOWING THE LOCATION OF LAKES SAMPLED
Wabatongushi Lake
CANADIAN PACIFIC RAILWAY
DUBREUILVILLE ROAD
Goldie Lake
Maskinonge Lake
Dog Lake
Troupe Lake
Herman Lake
ALGOMA CENTRAL RAILWAY
Summit Lake
Morrison Lake
Clearview Lake
Perry Lake
Selkirk Lake
Billboy Lake
Swanson Lake
Garbe Lake
17
Finger Lake
West Andre Lake
Andre Lake
Wallace Lake
Pivot Lake
Manitowik Lake
Parks Lake
Goetz Lake
651
Catfish Lake
Blueberry Lake
Bauldry Lake
Hawk Junction
Mildred Lake
Loonskin Lake
Brooks Lake
Black Trout Lake
PRECIPITATION COLLECTOR
Lena Lake
Hawk Lake
101
Arliss Lake
Lagarde Lake
Moran Lake
Wawa Lake
Whitefish Lake
SINTER PLANT
WAWA
Lake Superior
101
SCALE: KM
0
5
10
N

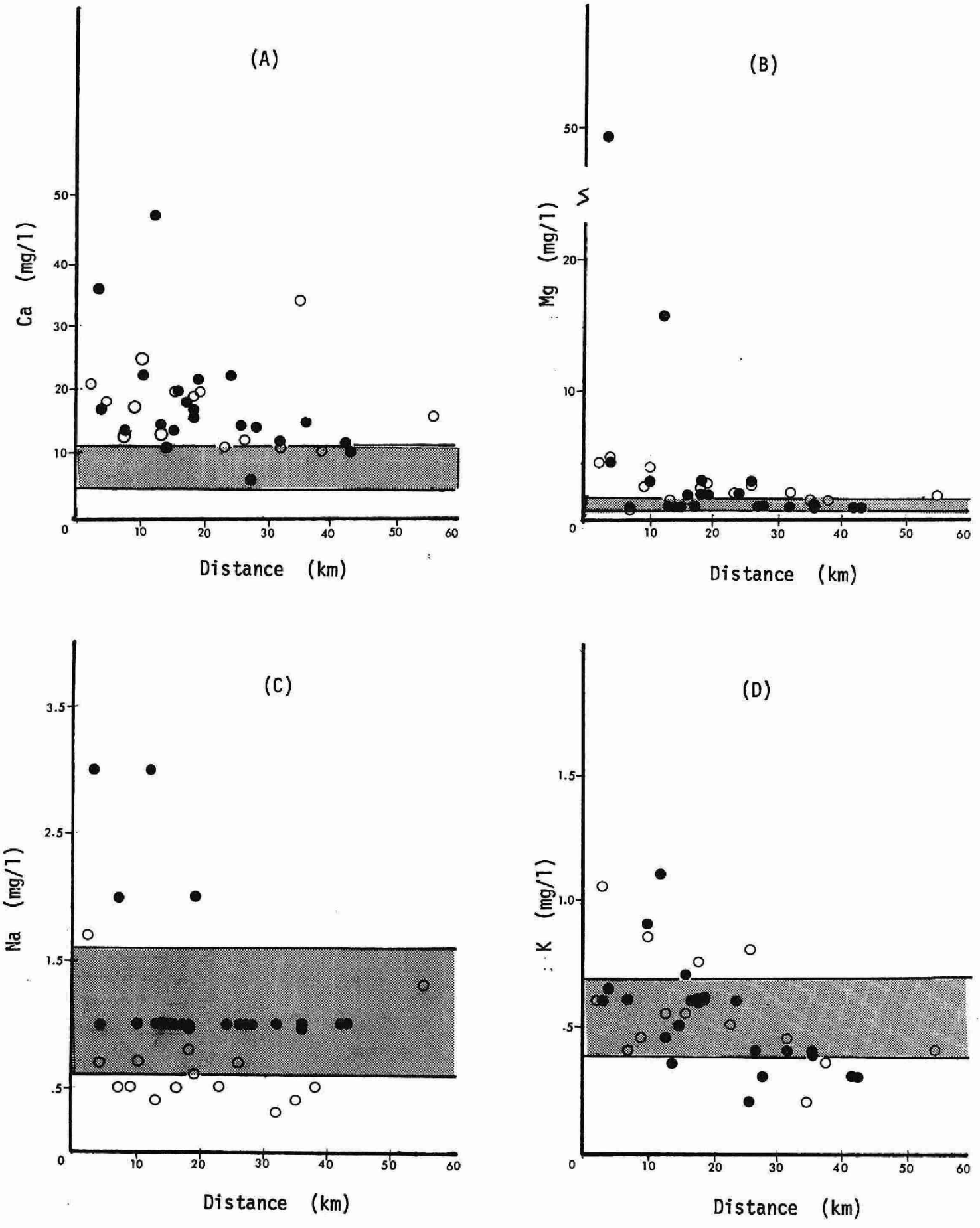
Figure 11

Figure 12

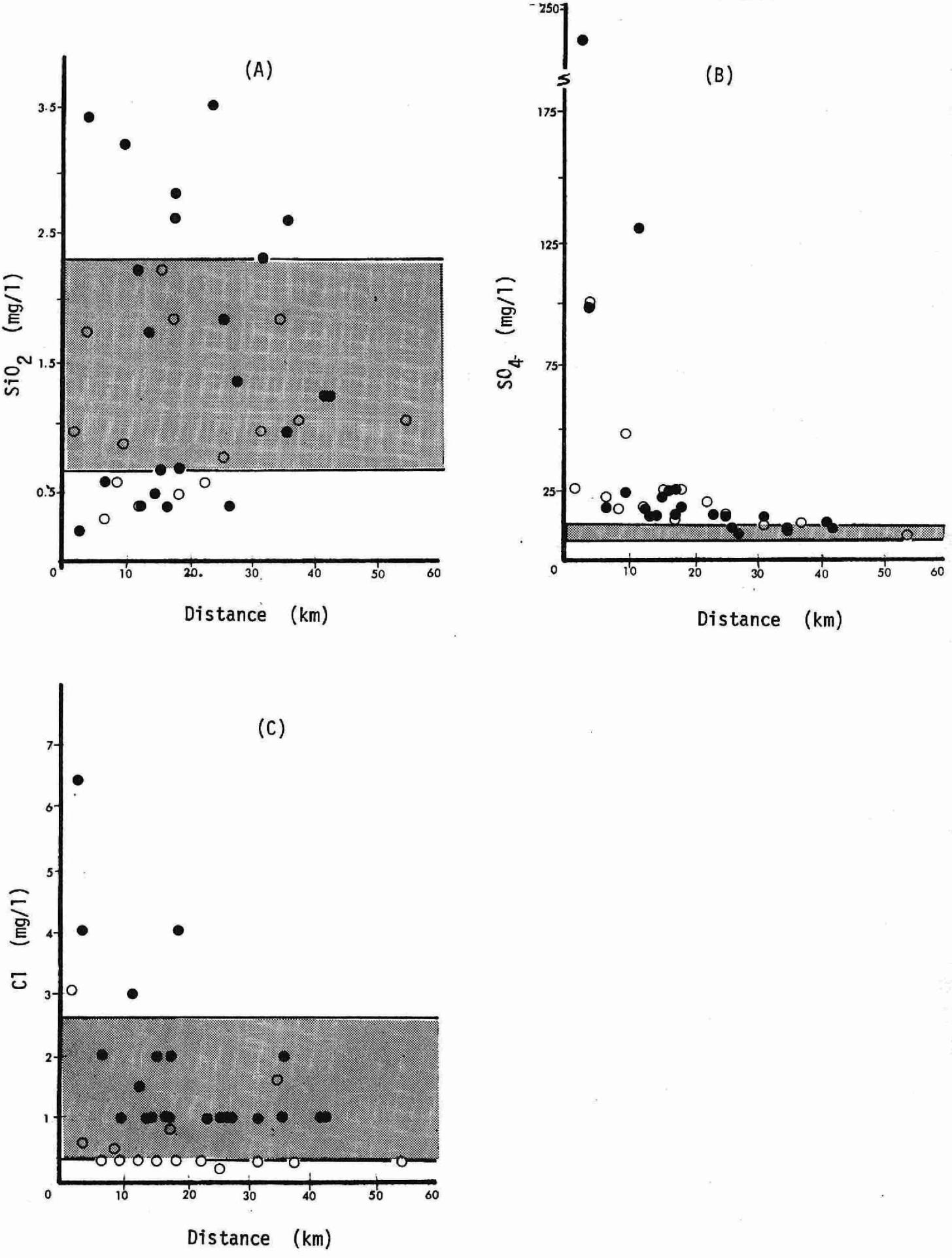
pH, ALKALINITY, HARDNESS AND CONDUCTIVITY IN THE STUDY LAKES.



CALCIUM, MAGNESIUM, SODIUM AND POTASSIUM CONCENTRATIONS IN THE STUDY LAKES.



SILICA, SULPHATE AND CHLORIDE CONCENTRATIONS IN THE STUDY LAKES.



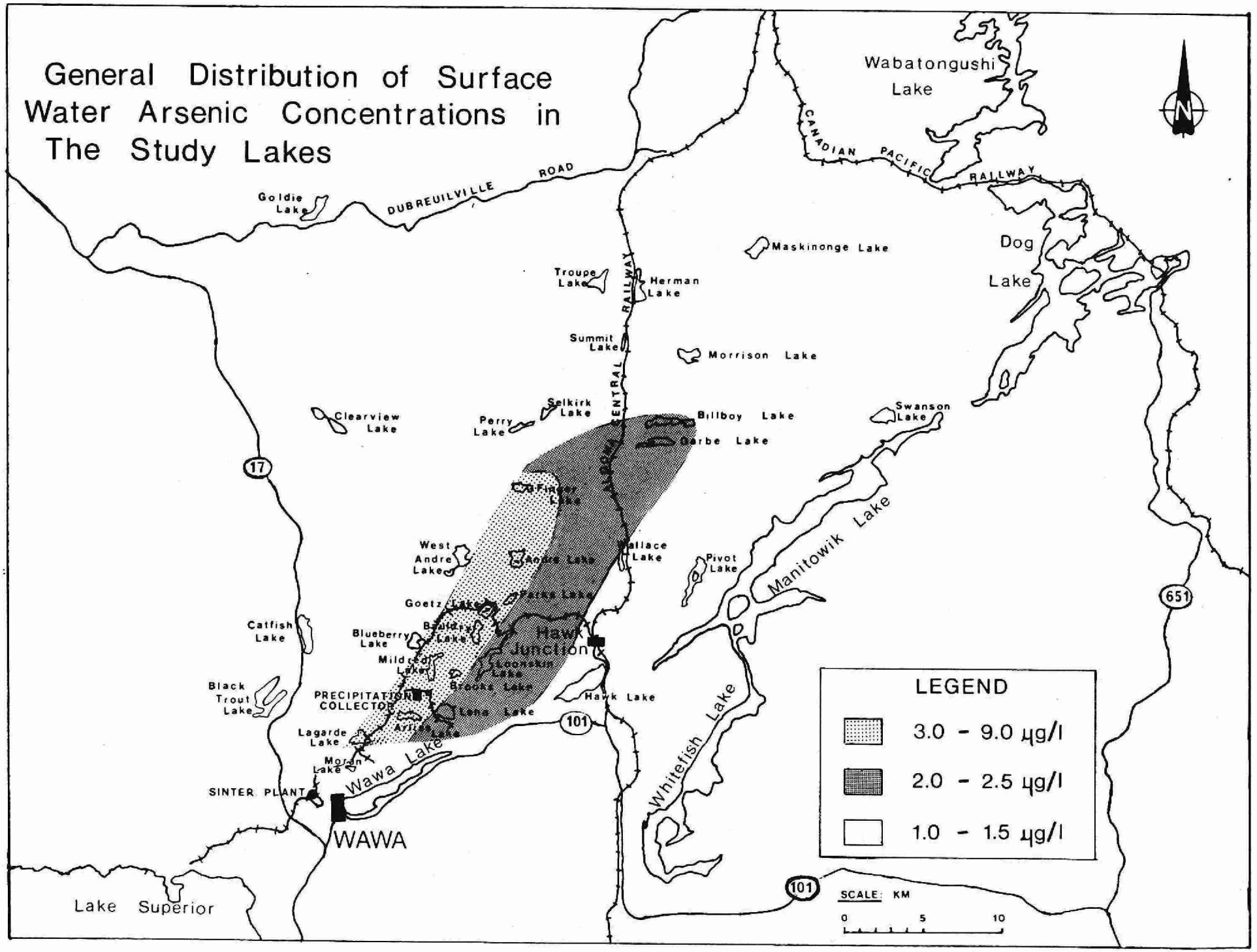
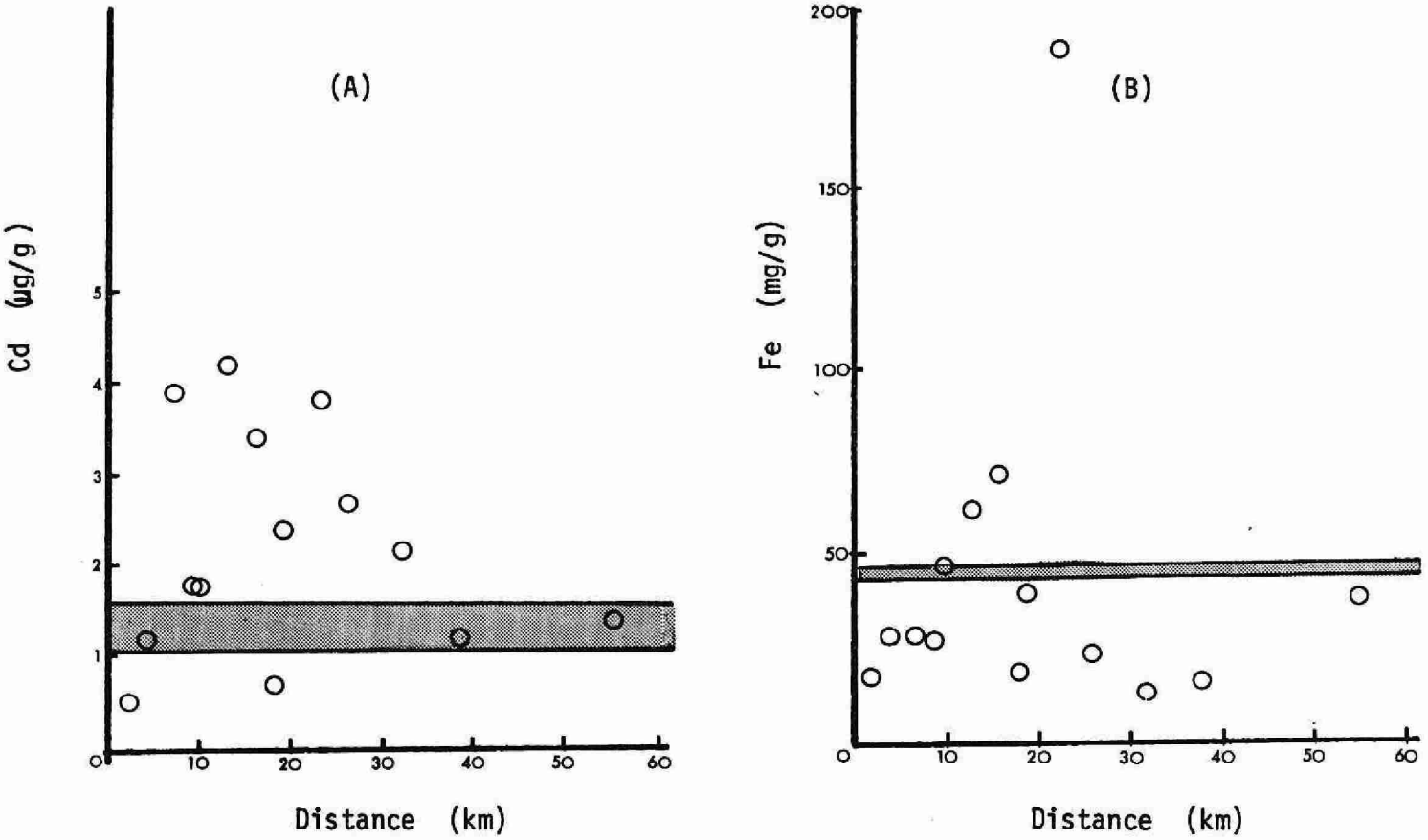

General Distribution of Surface Water Arsenic Concentrations in The Study Lakes
Wabatongushi Lake
CANADIAN PACIFIC RAILWAY
DUBREUILVILLE ROAD
Goldie Lake
Maskinonge Lake
Dog Lake
Troupe Lake
Herman Lake
ALGOMA CENTRAL RAILWAY
Summit Lake
Morrison Lake
Clearview Lake
Perry Lake
Selkirk Lake
Billboy Lake
Swanson Lake
Garbe Lake
17
Finlayson Lake
West Andre Lake
Andre Lake
Wallace Lake
Pivot Lake
Manitowik Lake
Goetz Lake
Parks Lake
Catfish Lake
Blueberry Lake
Boulder Lake
Hawk Junction
Mildred Lake
Loonskin Lake
Black Trout Lake
PRECIPITATION COLLECTOR
Brooks Lake
Hawk Lake
651
Lena Lake
101
Lagarde Lake
Arliss Lake
Moran Lake
Wawa Lake
Whitefish Lake
SINTER PLANT
WAWA
Lake Superior
LEGEND
3.0 - 9.0 µg/l
2.0 - 2.5 µg/l
1.0 - 1.5 µg/l
SCALE: KM
0
5
10
N

Figure 15

Figure 16

CADMIUM, IRON AND ARSENIC CONCENTRATIONS IN THE SEDIMENTS OF THE STUDY LAKES.



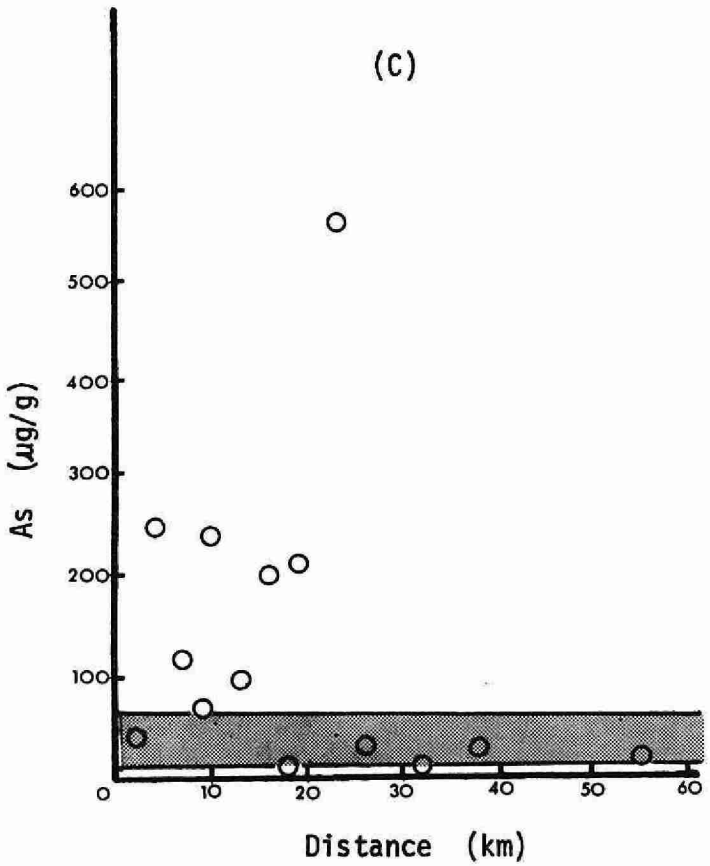


Figure 17

ZINC, COPPER, NICKEL AND LEAD CONCENTRATIONS IN THE SEDIMENTS OF THE STUDY LAKES.

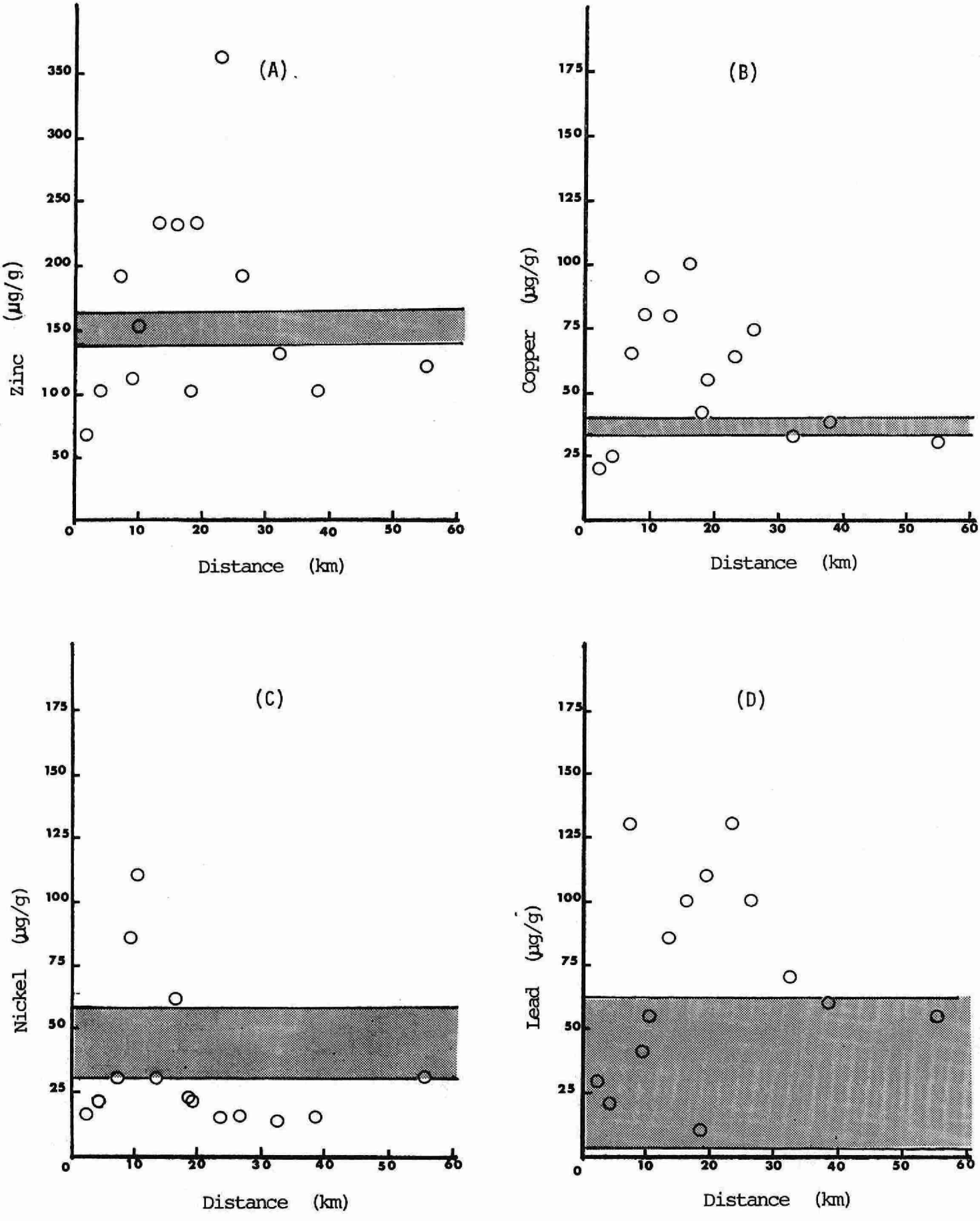
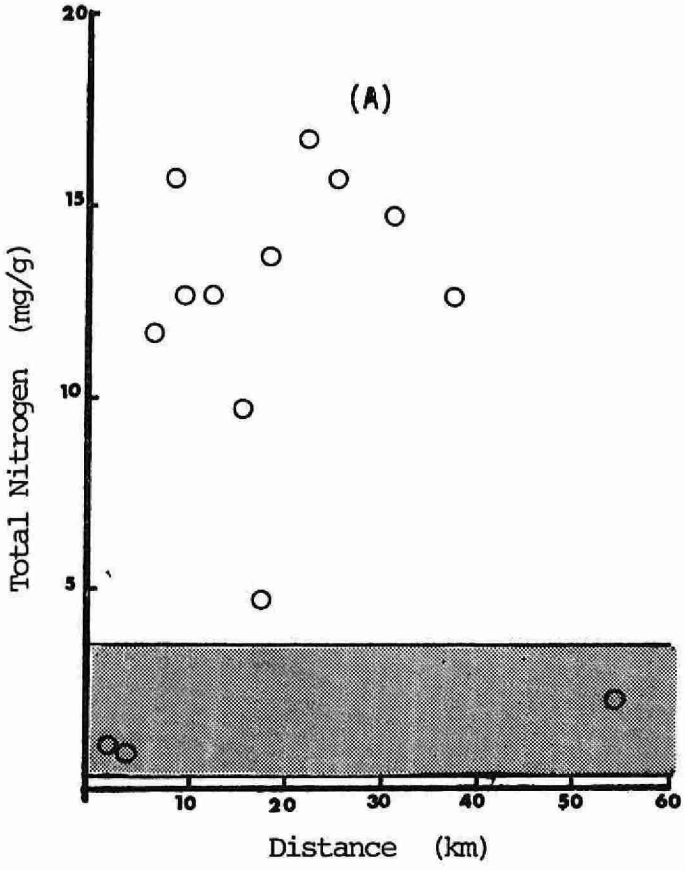
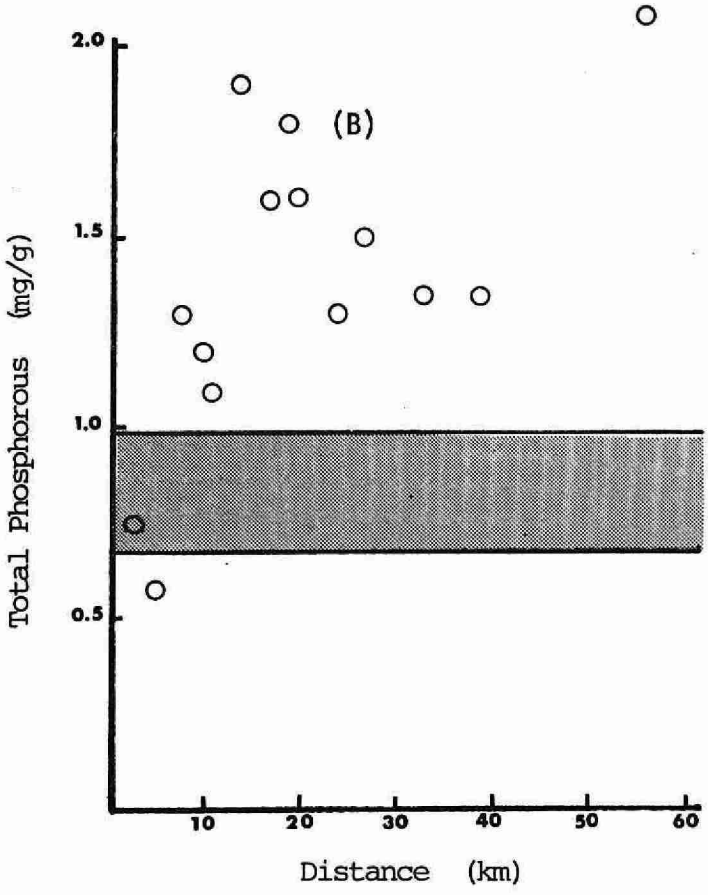
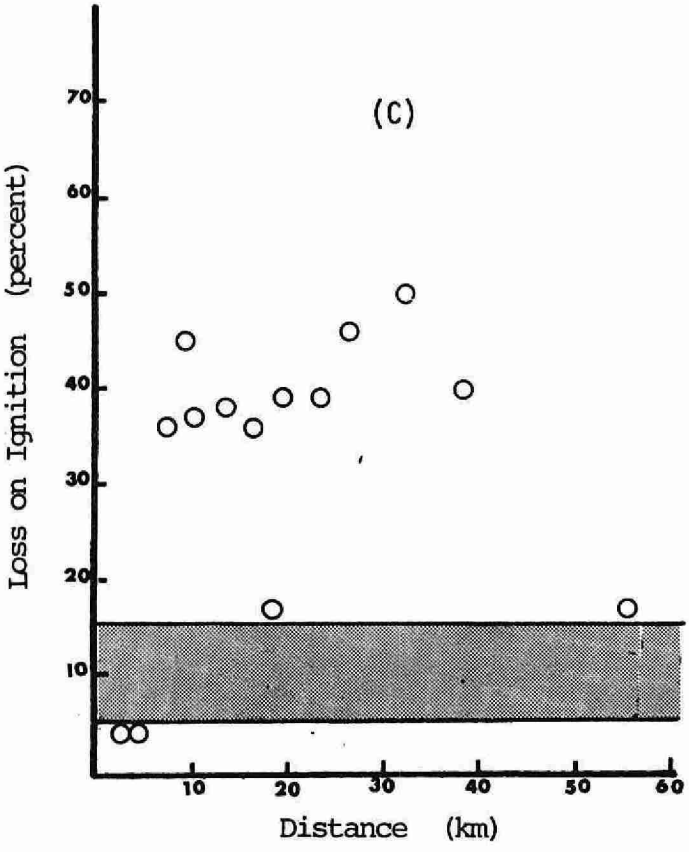


Figure 18

TOTAL NITROGEN, TOTAL PHOSPHORUS AND LOSS ON IGNITION IN SEDIMENTS OF THE STUDY LAKES.







PLOT OF SURFACE WATER pH VS. DISTANCE FROM THE WAWA SINTER PLANT (LINE REPRESENTS DATA FROM PRESENT STUDY, POINTS REPRESENT DATA FROM GORDON AND GORHAM, 1963)

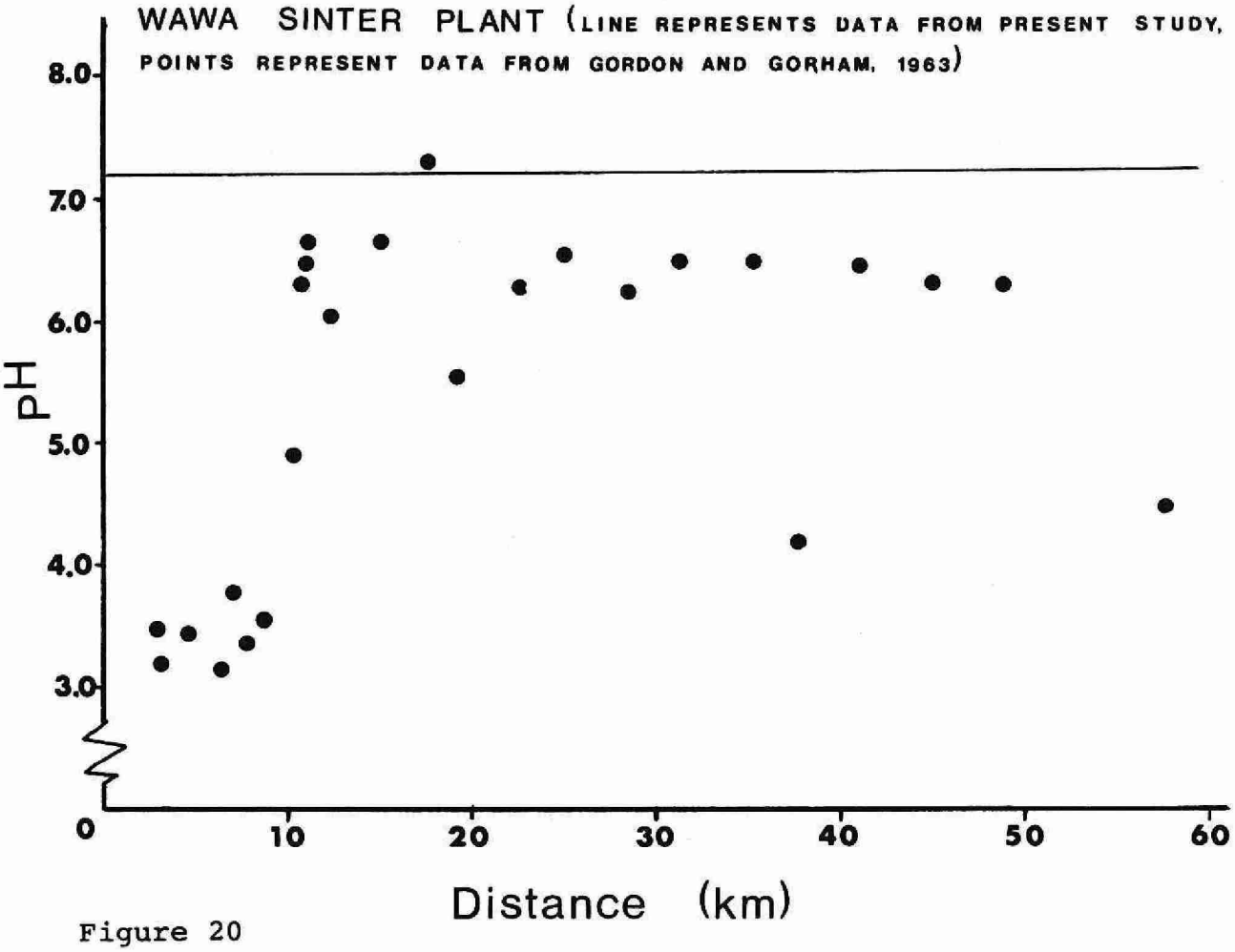


Figure 20

PLOT OF SURFACE WATER SO_4 VS. DISTANCE FROM THE WAWA SINTER PLANT (LINE REPRESENTS DATA FROM PRESENT STUDY, POINTS REPRESENT DATA FROM GORDON AND GORHAM, 1963)

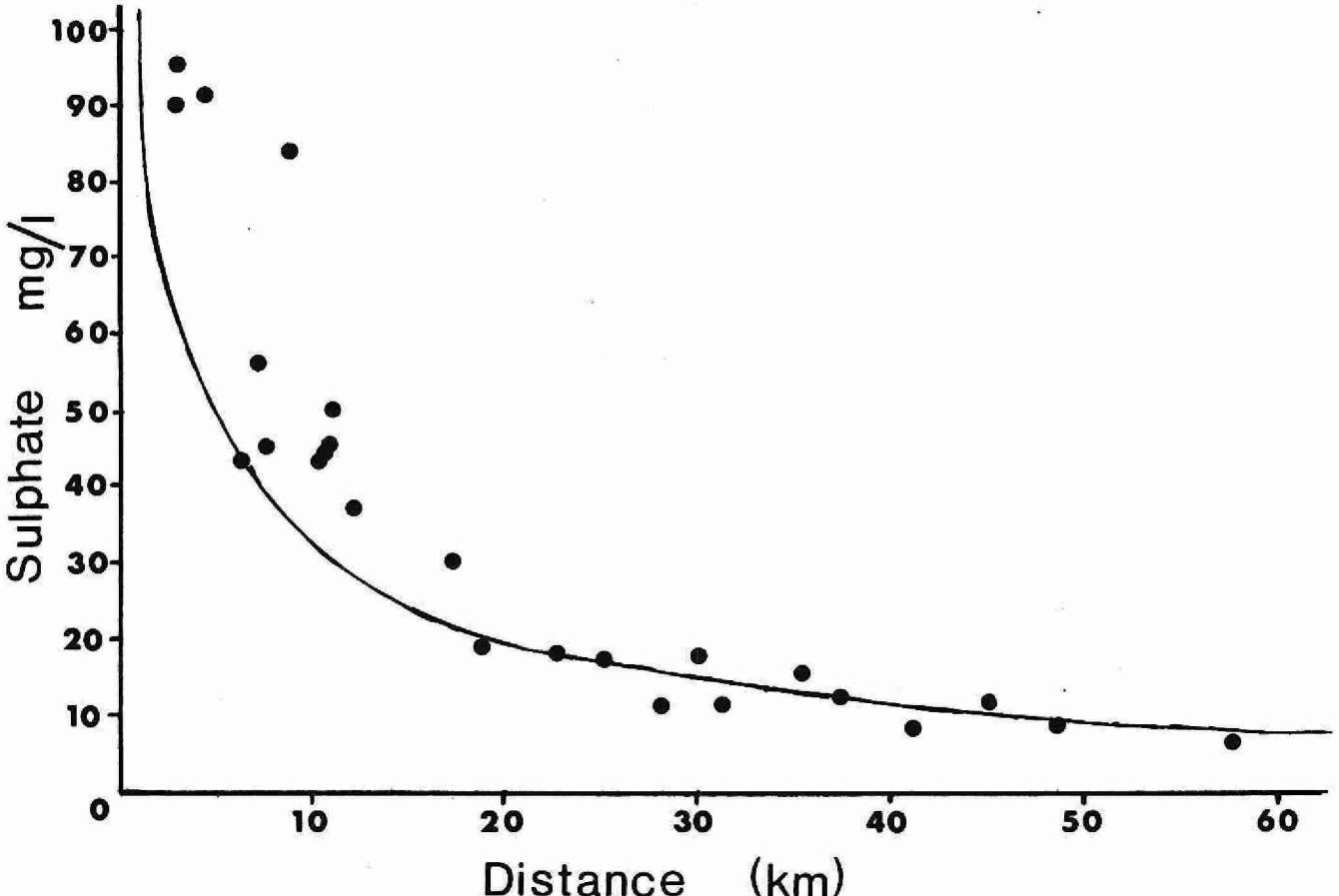


Figure 21

ARSENIC CONCENTRATIONS IN LAKE SEDIMENTS AND SOILS IN THE WAWA AREA